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Using Sustainability Education to Enable the Increase of Diversity in Science, Engineering and Technology-Related Disciplines*

JULIE BETH ZIMMERMAN[1] and JORGE VANEGAS[2]
[1]*Department of Chemical Engineering Environmental Engineering Program; School of Forestry and Environmental Studies; Center for Green Chemistry and Green Engineering at Yale; Yale University, New Haven, CT 06511–6815, USA. E-mail: julie.zimmerman@yale.edu*
[2]*School of Architecture, Texas A&M University, College Station TX, 77843 USA. E-mail: jvanegas@tamu.edu*

Science, engineering and technology (SET) are critical to achieving and maintaining a high quality of life, economic growth, global competitiveness, a clean environment and effective governance for the public good—some of the key characteristics of sustainability. A nation's ability to meet these goals significantly depends on the capacity and competency of its workforce to develop innovative products, processes and services that advance prosperity while maintaining and restoring environmental systems. In order to continue towards this paradigm shift, advance sustainability in the long term and supply a skilled and knowledgeable workforce to both the private and public sectors, educating the next generation in sustainability is critical. Engaging women and underrepresented groups in SET will build additional capacity in these fields that are critical to advancing economic, environmental and societal goals. There is an increasing amount of anecdotal evidence which shows that students are remarkably enthusiastic about education for sustainability and are engaged at many levels both within and outside the classroom. There may be several unique characteristics to the ideas and visions of sustainability that may contribute to making this concept especially attractive to women and underrepresented groups.

Keywords: sustainability; recruitment; retention; women; underrepresented groups; diversity; environment; green engineering

MOTIVATION AND DRIVERS

SCIENCE, ENGINEERING AND TECHNOLOGY (SET) are critical to achieving and maintaining a high quality of life, economic growth, global competitiveness, a clean environment and effective governance for the public good [1]—some of the key characteristics of sustainability. A nation's ability to meet these goals depends on the capacity and competency of its workforce to develop innovative products, processes and services that advance prosperity while maintaining and restoring environmental systems. The products, processes and services developed by SET contribute to bettering the quality of life in many capacities including increasing nutritional value, reducing disease, easing aging and improving safety. The discovery and innovation in SET fuels economic growth and translates into competitiveness [1]. Advances in SET lead to higher productivity while minimizing the use and generation of hazardous substances, improving material and energy efficiency, and advancing the use of benign and renewable chemical and energy feedstock [2]. Finally, research and development in SET provide the knowledge and foundation for effective policy-setting and decision-making in terms of regulations, laws, incentives and voluntary programmes. From this, it is clear that SET will continue to play a vital role in the overall wellbeing of the economy, society and the environment and ultimately in achieving the goal of sustainability.

The role of science, engineering and technology in advancing these goals is becoming more apparent with recent trends toward sustainability in industry and academia as well as in governmental and non-governmental organizations (NGOs). This will build on a long tradition of scientists, engineers and technologists responding to societal needs in terms of researching and developing transportation, sanitation, health care, communication, energy production, waste management and pollution control systems [3]. The private sector is embracing sustainability as evidenced by the world's largest engineering company, General Electric, launching Ecomagination as a strategic opportunity for the business and the environment [4], with *Fortune* 100 companies naming Chief

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Sustainability Officers [5], with the Dow Jones and FTSE indexes developing analogous indices for corporate social responsibility and sustainability that have outperformed their traditional counterparts [6] and with the establishment of groups such as the World Business Council for Sustainable Development [7].

The trend in academia seems to be mirroring that of the private sector. Since the United Nations Stockholm Conference on the Human Environment in 1972, there has been growing international interest in the role of higher education in fostering a sustainable future [8]. Agenda 21 [9] and a series of higher education for sustainable development declarations in the 1990s made this agenda explicit. At a growing number of institutions across the United States, highly motivated and committed presidents, faculty and staff members and students have begun to implement this agenda with colleges and universities increasingly adopting sustainability initiatives [8]. Engineering and technology schools are clearly engaging in the sustainability challenge, as illustrated by the programmes at the Georgia Institute of Technology (Georgia Tech), Arizona State University, Michigan Technological University, and Carnegie Mellon University, among others.

This type of focused attention on sustainability is also evident in government at all levels and NGOs. The international governing body, the United Nations (UN), has put a specific emphasis on sustainability with conferences such as the Rio Summit and the World Summit on Sustainability in 2002, with the development of Millennium Challenge Goals and with the launching of the UN Decade of Education for Sustainable Development. This emphasis on sustainability is also evident at National levels with the release of Canada's Sustainability within a Generation report [10] and New Zealand's Creating our future: Sustainable development for New Zealand [11]. State and local governments are also paying specific attention to sustainability when making decisions on planning for future growth and developing new buildings. Similarly, the NGO community has made an explicit commitment to advancing sustainability with the launch of activities focused on the 'bottom of the pyramid' and grassroots activities in local developing world communities to ensure safe drinking water, a stable food supply, adequate shelter and appropriate healthcare.

In order to continue towards this paradigm shift, advance sustainability in the long term and supply a skilled and knowledgeable workforce to both the private and public sectors, educating the next generation in sustainability is critical. For the reasons discussed earlier, the science, engineering and technology workforce will be especially crucial to advancing these goals. An even greater challenge than educating the next generation in these disciplines is addressing the current lack of diversity or representativeness in SET education and practice and how improving diversity can improve the effectiveness of science, engineering and technology for sustainability.

Demographic trends inspire concern about the nation's ability to meet its future SET workforce needs. Historically, non-Hispanic white males have made up a large fraction of U.S. scientists, engineers, and technologists. However, in the 21st century this portion of the US population is projected to decrease significantly. Other US population groups, such as women, Hispanics and African-Americans, form a much smaller part of the SET workforce, but their populations are expected to increase markedly in the next 50 years [1]. This implies that the SET fraction of the total workforce may decline if the relative participation rates of these traditionally underrepresented groups remain at their present levels. Given these trends, it is important to look to the workforce pipeline and enrollment trends in SET disciplines at US colleges and universities. Given that women and traditionally underrepresented groups make up a small number of the enrollment in SET disciplines [12] and that the diversity in the general US population is projected to increase with time [13], it is clear that the current SET pipeline is not reflective of the current or future population and that current and future demand levels for scientists, engineers and technologists may not be met. If a strong SET workforce is to be ensured, it is imperative that members of all groups, including non-Hispanic white males, participate at increasing rates [1].

Engaging women and underrepresented groups in SET will build additional capacity in these fields that are critical to advancing economic, environmental and societal goals. These new additions to SET fields will introduce perspectives that may be crucial and are not well represented in current approaches, strategies, designs and actions [1]. Recent research has documented the contributions of diversity in higher education, in the community, and in the workplace [14, 15]. One study of innovations in organizations by Rosabeth Moss Kanter, professor of business at Harvard, found that highly innovative organizations make it a practice to use heterogeneous work terms [16]. Diverse multi-stakeholder representation can significantly advance the success in solving, satisfying, capitalizing and realizing today's challenges, needs, opportunities and aspirations. Furthermore, as the nature of the challenges, needs, opportunities, and aspirations in the future become more complex, requiring broader and more holistic perspectives, diverse multi-stakeholder representation in SET will become an imperative. Given that:

- the SET disciplines are critical to the maintaining and achieving economic, environmental and society goals;
- there is a lack of women and underrepresented groups training and working in SET fields;

- the projected demographic trends suggest minority population segments are increasing;
- the perspectives of women and underrepresented groups would improve the ability of SET to address current and more complex future challenges, needs, opportunities and aspirations.

The SET community should strive to find effective means of engaging these vital population segments in science, engineering and technology-related disciplines and careers. Since it takes many years to train a scientist or engineer, it is important to explore strategies for increasing recruitment and retention in SET disciplines today guaranteeing the availability of a skilled and competent workforce for the 21st century.

One strategy that has begun to emerge as a potentially significant contributor to achieving this goal is the introduction of sustainability into SET curriculums. There is an increasing amount of anecdotal evidence that shows that students are remarkably enthusiastic about education for sustainability and are engaged at many levels both within and outside the classroom [17]. There may be several unique characteristics to the ideas and visions of sustainability that may contribute to making this concept especially engaging to women and underrepresented groups.

THE ESSENCE OF SUSTAINABILITY

Establishing the essence of sustainability provides an important understanding of why this concept may be a valuable means to enable the recruitment and retention of women and underrepresented groups in science, engineering and technology related disciplines. The challenge with introducing sustainability is that the literature on the topic is rich, extensive and diverse with many different definitions [2]. For the purpose of this paper, five fundamental elements and five dimensions will be used to define the essence of sustainability as shown in Fig. 1.

People are the first and most important element of sustainability. Sustainability is about continuously enabling, maintaining, and nurturing the bodies (i.e. the physical health), the minds (i.e. the education), the hearts (i.e. the emotional state) and the souls (i.e. the spiritual dimension) of individuals (i.e. men, women and children), within families, communities and organizations,

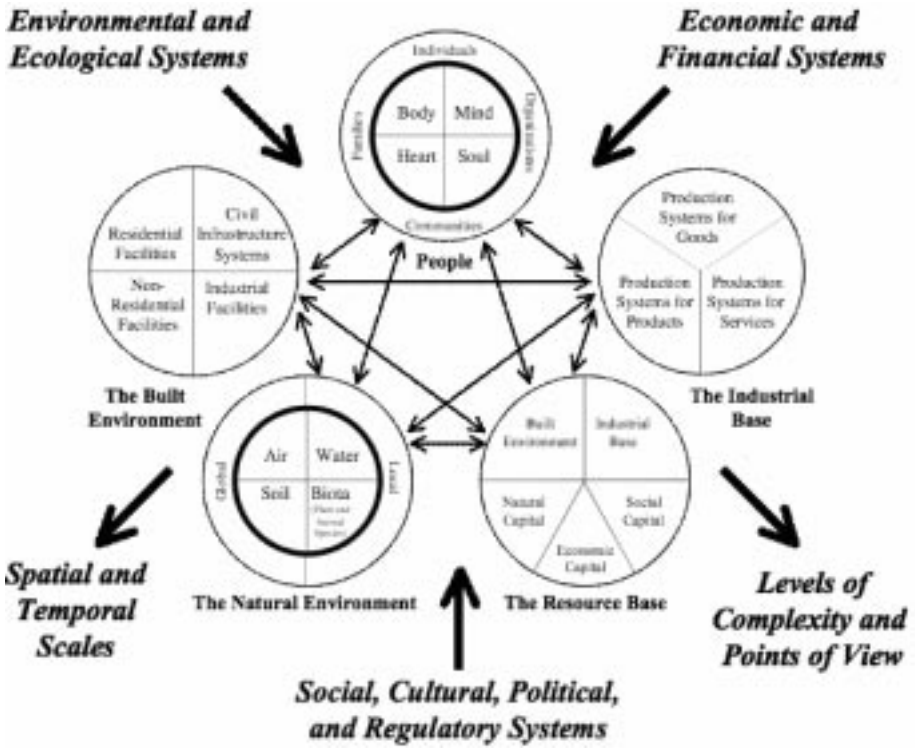


Fig. 1. The Fundamental Elements and Dimensions of Sustainability [from 18].

in both the public and the private sectors of any nation in the world.

The needs and aspirations of people, and also, their levels of quality of life, are a function of three additional elements of sustainability:

1) the Built Environment;
2) the Industrial Base;
3) the Natural Environment.

These three elements play critical roles in ensuring sustainability. To exist, grow and develop, and even survive, societies depend on: first, the quality, integrity and performance of their residential facilities, non-residential facilities and industrial facilities (e.g. houses, clinics and hospitals, schools and universities, churches, offices, stores and supermarkets, shopping centres, sports venues, and manufacturing facilities, among others), and their civil infrastructure systems (e.g. water supply, sewage, energy, transportation and communication systems, among others); second, the quality, integrity and performance of their production systems for the manufacture of products, supply of goods and provision of services (e.g. all types of consumer, commercial, manufactured and industrial products, agricultural goods and professional and social services, among others); and third, of the quality, integrity and health of the air, water, soil and biota within their environmental and ecological systems.

The final element of sustainability is the Resource Base, which includes economic capital and four additional types of capital stemming from the four elements described above: social capital, the capital invested in facilities and civil infrastructure systems within the built environment and in the production systems within the industrial base, and natural capital. To exist, grow and develop, and even survive, societies also depend on these resources.

Sustainability is, in essence, a system of systems. Each of its elements represents a complex system that can be further broken down into numerous hierarchical levels of subelements, subsystems and components, within which many and diverse fields of study, disciplines and bodies of knowledge converge and interact with each other. The ultimate goal of sustainability is to ensure that the five elements defined above have the ability and the means to satisfy the needs and aspirations of people within all societies in the world today, providing, maintaining and improving their quality of life, while at the same time, ensuring that they retain the ability and the means to satisfy the needs and aspirations of future generations.

Advancing sustainability can address local environmental, economic and societal challenges in real terms. And as was discussed earlier, science, engineering and technology-related disciplines are fundamental to advancing the goal of sustainability. As such, education for sustainability may present a significant opportunity for the recruitment and retention of women and traditionally underrepresented groups in SET-related disciplines. Similarly, advancing the goal of sustainability will require the insight, perspectives and engagement of a more diverse stakeholder group educated in SET. In other words, the cause—a sustainable future—that may inspire these population segments to pursue and remain in a SET discipline is also one of the most significant drivers to diversify the stakeholder group that is engaged in researching and developing the science, engineering and technology necessary to achieve a sustainable future.

THE OPPORTUNITY

The nature and essence of sustainability offers an opportunity to transcend the traditional scope and boundaries of science, engineering, and technology. As shown in Fig. 2, the elements and dimensions of sustainability can be drivers of research questions, problems, needs, opportunities or aspirations, which can then be pursued within the formal conventional education path, or within a service learning path. Cognitive research has shown that meaningful learning, as well as intellectual and social maturity, is stimulated when students learn in groups, actively build, apply and share their own knowledge. encounter diverse perspectives that challenge their assumptions, negotiate and build consensus and reflect on implications [19]. This suggests that education for sustainability, which requires many of these attributes, can serve as a driver to recruit and retain students in SET disciplines. There has been some evidence of schools using course offerings in environmental justice and international sustainable development as a strategy for increasing diversity enrollment [17]. In both the formal and service learning paths, the results are answers to the research questions, solutions to problems, satisfaction of needs, realization of opportunities or fulfillment of aspirations. These outcomes add to the body of knowledge of science, engineering, and technology while advancing the goal of sustainability.

Sustainability is an important driver and vital outcome because the nature of problems, needs, opportunities and aspirations today, and even more so tomorrow, requires a workforce that is fluent and competent in systems thinking, has a holistic perspective on issues, demonstrates contextual competence and possesses an awareness of the impacts of their decisions, choices and actions on various spatial and temporal scales. The workforce must also incorporate the social, environmental and economic dimensions in the solution of problems, satisfaction of needs, capitalization of opportunities and realization of aspirations.

Education in sustainability offers an opportunity to tap into the existing pool of women and other traditionally underrepresented groups, and attract them to pursue SET professions. As a

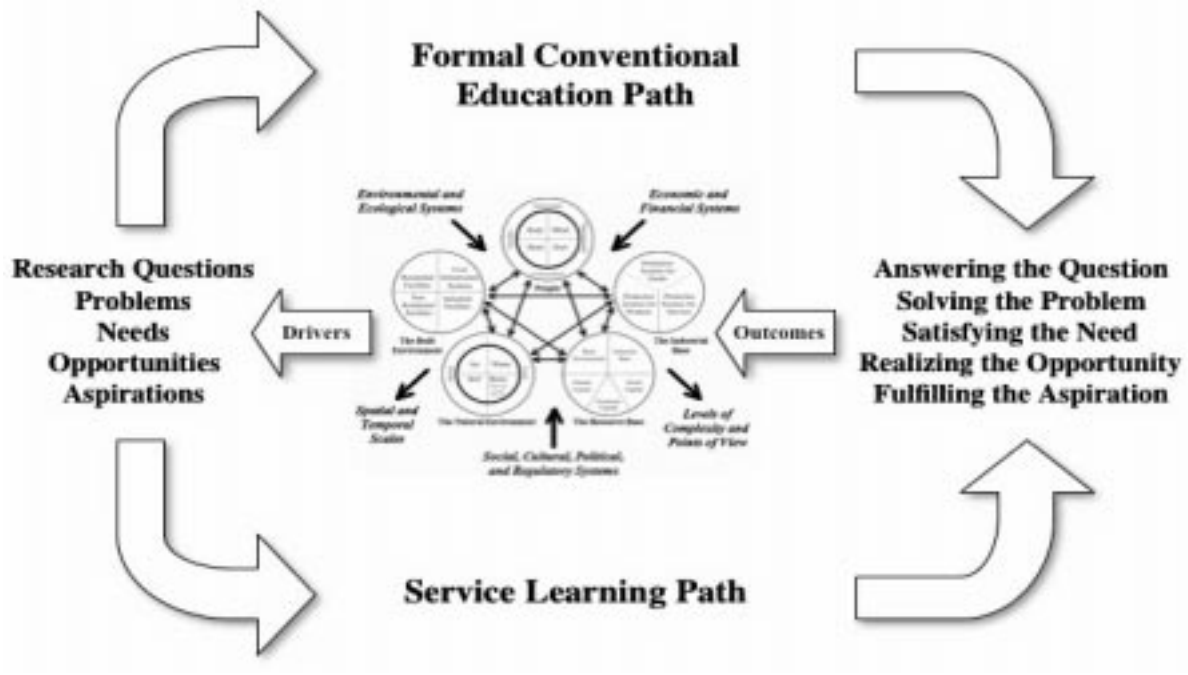


Fig. 2. Opportunity of sustainability for SET.

result, these steps can close the disparity in representation within the demographic profiles of society (as an initial pool of potential talent), of academia (as the platform that develops this talent) and of the workforce in industry, academia and government and NGOs (as the ultimate users of this talent). In addition, it can expand the horizons of these individuals beyond the traditional boundaries of SET-related disciplines into the dimensions of social, environmental and economic sustainability, while developing an intellectual 'toolkit' (e.g. systems thinking, holistic perspective, contextual competence and increased awareness of the impacts of their decisions, choices and actions on various spatial and temporal scales), which will enable them to address these dimensions in a meaningful and effective way. These individuals will then be trained as a member of the SET workforce educated in sustainability and can have potentially significant impacts on industry and academia as well as government and NGOs.

THE VISION

At the very least, conservative estimates indicate that the nation will need to maintain the current fraction of its workforce devoted to science, engineering and technology [1] but it is most likely that the future demand will have to be met through increased diversity in the future SET workforce. While it is suggested that education for sustainability may be a useful tool to meet the demand for recruiting and retaining the SET workforce as well as increasing diversity in that workforce, there also is additional benefits in terms of the knowledge and skills of this future workforce. Building capacity for a SET workforce educated in sustainability that is diverse and inclusive will serve a fundamental component of achieving sustainability. The vision of this diverse workforce is one that is educated in SET-related disciplines as a foundation, and is trained in the various dimensions of sustainability as a complement and enhancement of traditional science, engineering and technical education. The goal would be a workforce that is first and foremost technically competent with solid scientific and technical knowledge while having an understanding of the unique challenges and perspectives of sustainability. This will create a driven, engaged, empowered and equipped workforce that is an agent of change towards sustainability within various SET related disciplines and across a wide array of sectors including industry, academia, governments and NGOs.

While the effects in industry, government and NGOs may be obvious in terms of improved material and energy efficiency, enhanced economic competitiveness, more effective policy and decision-making and better communication and collaboration on key issues, the impacts on the academy may be the most significant given the multiplier effect of training multiple students and future leaders across disciplines and sectors at one time. If the future workforce is necessary to achieving sustainability, the burden of educating and training this workforce falls to the academy. This would suggest that there is an opportunity for the academy to explore strategies and approaches to provide a significant service to society by providing a sound and rigorous SET education while enhancing this knowledge with an awareness of sustainability.

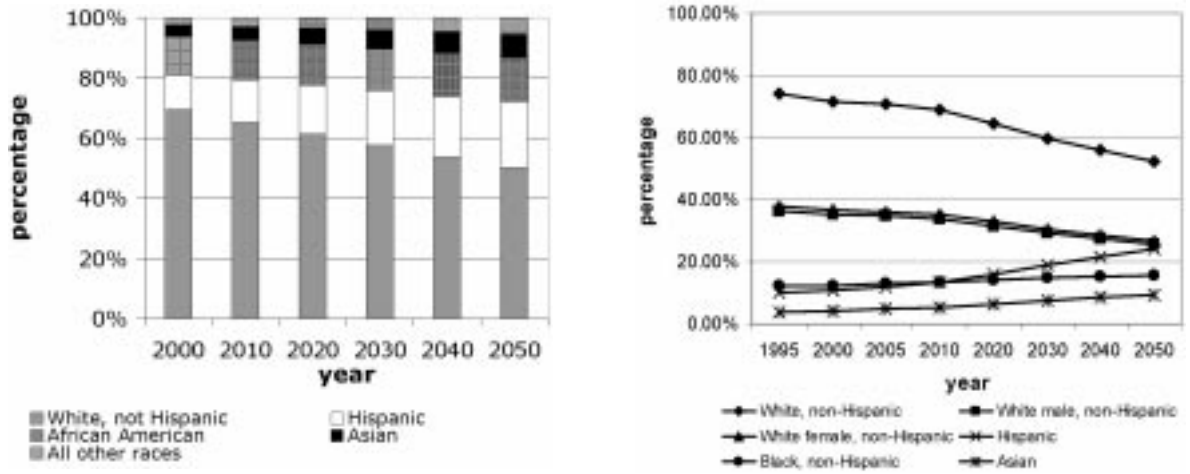
There are numerous ways to create a diverse and inclusive academy and potential considerations could include a more pronounced focus on diversity and opportunities for sustainability and service learning while maintaining the current high quality of education in a nurturing the environment. Valuing a diverse student body would suggest actively pursuing, recruiting, retaining and developing a diverse student population. Valuing diversity in the academy's leadership would suggest actively pursuing, recruiting, retaining and developing a diverse faculty and administration population. Having this type of highly qualified, diverse faculty population can have a significant impact in terms of recruiting and retaining women and underrepresented groups by leading by example and by providing role models and mentors. While maintaining the intellectual rigor and quality of education in SET-related disciplines and carrying this tradition forward to new areas, educational opportunities and experiences in the various dimensions of sustainability could be created to complement and enhance the current SET education. In addition, the academy could foster and maintain a nurturing educational environment that promotes curiosity, discovery, creativity, innovation and, most importantly, scholarship in the solution of challenges, satisfaction of needs, capitalization of opportunities and realization of aspirations, within the context of sustainability.

This type of academic system may have the potential to expand the pool of women and members of other traditionally underrepresented groups rigorously trained in science, engineering and technology disciplines with the enhancement of a fundamental understanding of sustainability. These population segments, traditionally underrepresented in SET fields, can now serve as an effective and productive force in advancing the innovation in science, engineering and technology contributing to further growing and developing these fields and enhance SET in achieving and maintaining a high quality of life, economic growth, global competitiveness, a clean environment and effective governance for the public good, cornerstones of a sustainable future. In addition, this type of academic system and an emphasis on sustainability education may produce the next generation of scientists, engineers and technologists with enough understanding and awareness about how they can directly contribute to local communities in the developed and developing world, and to society through their knowledge, experience and skill set.

THE BASELINE

In order to understand and appreciate the current status and potential future crisis in the SET workforce, it is helpful to explore the current demographic trends in the general population and the current workforce as well as the current demographic trends in enrollment and graduation in SET disciplines.

Much of the concern about the future SET workforce arises from demographic trends that, given the structure of the current workforce, could have significant detrimental consequences. According to the Bureau of Census projections in Fig. 3, the overall population is becoming more diverse as is the workforce population (ages 18 to 64). Non-Hispanic white males, the present majority of the US SET workforce, will decline as a fraction of the overall population from 70 to 50 per cent and from population 18 to 64 years of age (the workforce) from 37 per cent in 1995 to 26 per cent



(a) (b)

Fig. 3. Projected demographic changes in the A) the general population and B) the workforce population (18 to 64 years old) through 2050. The middle series projections were used. The workforce was taken as the group, ages 18—64 years old. Data for those ages 18 and younger and those ages 65 and older were used to derive the numbers for the group with ages 18—64 years. The US Bureau of the Census Population Projections Programme produces projections of the US resident population by age, sex, race and Hispanic origin. The projections are based on assumptions about future births, deaths and international migration. [1, 13, 20]

in 2050. From 1995–2050, the workforce is expected to change from 12 to 14 per cent African-American, 10 to 24 per cent Hispanic, 4 to 9 per cent Asian, and from 74 to 52 per cent non-Hispanic white. As a result, minorities are expected to increase from a quarter of the workforce to nearly half (48 per cent).

Historically, non-Hispanic white males have formed the bulk of the US SET workforce. This current underrepresentation of the larger minority population groups, African-Americans and Hispanics, in the SET workforce leads to the question of what likely impacts the projected demographic changes will have on the current pipeline and future professionals. The SET workforce is largely maintained by a flow into the workforce of college and university graduates with SET bachelor's degrees. In Fig. 4, the leftmost vertical bar in each ethnic/gender grouping gives the group's percentage of the US population. The bars to the right indicate, successively, the percentage of SET degrees awarded, SET graduate school enrollment and SET labour force represented by that group. In 2001, non-Hispanic white men comprised 34 percent of the population but accounted for 67 per cent of the SET workforce, 38 per cent of the SET bachelor's degrees awarded, and 42 per cent of enrollment in SET graduate studies (see Fig. 4). Non-Hispanic African-American men were 6.2 per cent of the population, 3.2 per cent of those receiving bachelor's degrees, 3.1 per cent of the graduate enrollment in SET and only 2 per cent of the SET labour force.

In 2001, women earned almost half of the SET bachelor's degrees but only 43 per cent of the master's degrees and 37 per cent of the doctorates [12]. With the exception of Asian men, the percentages of minorities in science and engineering fall off at successive levels of advancement, from undergraduate to graduate work and into the workforce. This is particularly significant for both underrepresented groups and women, because it is the Ph.D. degree that enables these people to join university faculties. If only a small fraction of underrepresented groups and women pursue advanced degrees, there are a reduced number of people available to lead by example and serve in the vital capacities of role models and mentors to encourage other minorities and women to pursue SET careers and enter the SET workforce. Taken together, women and underrepresented groups make up a half to two-thirds of the population of the United States and are now the nation's new majority. Far larger numbers of scientists and engineers must come from the talent pool made up of this new majority, not to displace any group, but to expand the nation's capacity to innovate within a framework of inclusiveness and opportunity [21].

THE PATH FORWARD

There are numerous efforts underway to integrate sustainability into the SET curriculum and a significant amount of anecdotal evidence to

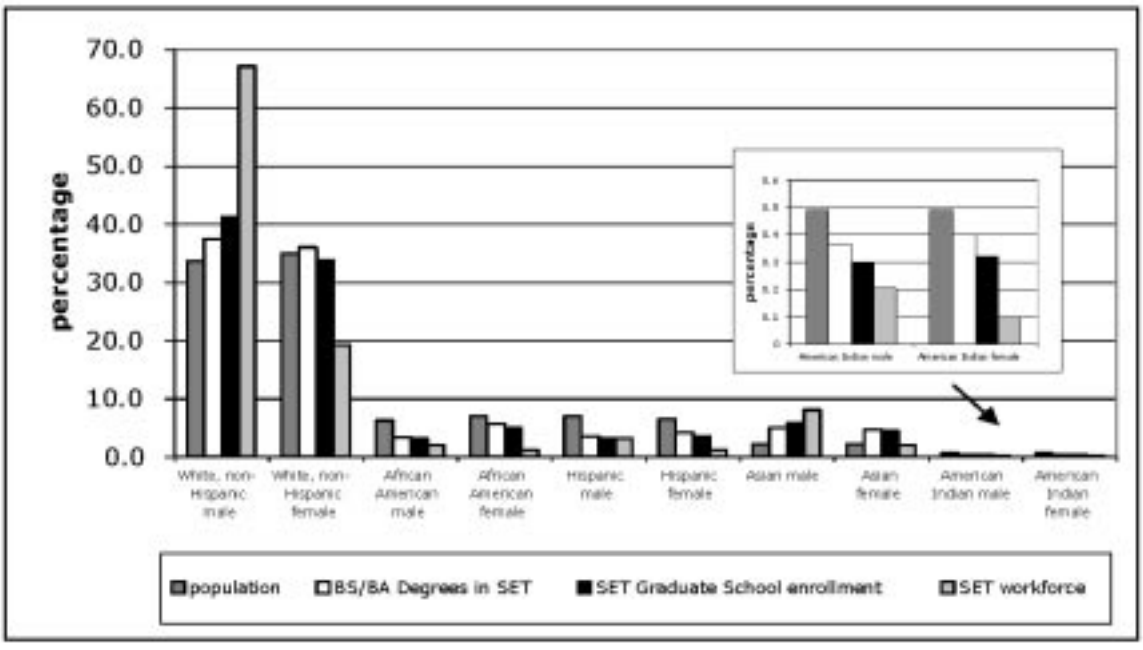


Fig. 4. Percentage of population (2000) [13], SET Bachelor's Degrees Awarded (1999). (Figures are for 1999 and for U.S. citizens and permanent residents only. Total includes persons of unknown race/ethnicity) [12], SET Graduate School Enrollment (1999) (Figures are for US citizens and permanent residents only. Total includes persons of unknown race/ethnicity) [22], and SET workforce (1999) (Includes scientists and engineers currently employed in SET occupations, or unemployed scientists and engineers whose last job was an SET occupation. Figures include all persons who have ever received a bachelor's degree or higher in a SET field, plus persons with a non-SET bachelor's degree or higher employed in an SET occupation during the 1995, 1997 and/or 1999 SESTAT surveys [23]. Figure was updated and modified from Figure 2–1 in [1].

support the notion that these curriculum changes are enabling an increase in the recruitment and retention of women and underrepresented groups. Demographic data from current research groups focused on science, engineering and technology for sustainability can also be used to indicate if a relationship does exist between education for sustainability and diversity. Another place that may provide insight into this connection is the demographics of student chapters focused on SET for sustainability such as Engineers without Borders and the Green Chemistry student chapters of the American Chemical Society.

Numerous engineering and technological institutions in the United States are turning their education and research toward sustainability. Georgia Tech, a leader in this area, hosts the Institute for Sustainable Technology and Development, now the campus advocate for sustainability in curriculum, research and operations [24]. Georgia Tech also supports the Environmentally Conscious Design and Manufacturing Programme, which integrates a long-term research agenda with ongoing economic development activities in Georgia [25]. For data reported on diversity enrollment from 1999—2004 in the Mechanical Engineering Department where this programme is housed, Georgia Tech is above the national percentage for enrollment for African Americans, total and women, and Asian Americans, total and women (Fig. 5) with nearly twice the National average of enrolled African American women. This suggests that there may be some correlation between this curriculum and diversity enrollment but the results are mixed given that Hispanics, total and women, are generally underrepresented in the department despite this curriculum

Another established leader in education for sustainability in SET disciplines is Carnegie Mellon University (CMU). CMU has an active faculty and administration engaged in pursuing education for sustainability. For example, the universityrecently established a new course, 'Nature, Ecology and Sustainable Design', that gathers students from all over the university to discuss and critique the definition and the development of sustainability [26]. The undergraduate and graduate students taking the class have backgrounds ranging from design art, and architecture to engineering, computer science, environmental studies and anthropology. This course was created to give students a better understanding of the broader philosophical issues involved in sustainable design and the different approaches that are emerging in contemporary culture. The Civil Engineering Department at CMU hosts the Green Design Institute focused on establishing partnerships for a sustainable environment and economy. The institute is a major interdisciplinary research effort to make an impact on environmental quality through green design. The central idea of the institute is to form partnerships with companies, government agencies and foundations to develop pioneering design, management, manufacturing and regulatory processes that can improve environmental quality and product quality while enhancing economic development.

For data reported on diversity enrollment from 1999—2004 in the Civil Engineering Department, CMU is above the national percentage for enrollment for African Americans, total and women, and Asian Americans, total and women (Fig. 6 with nearly twice the National average of enrolled African American and significantly greater enrollment of Native American women than the national average. These results again may support a correlation between sustainability and diversity enrollment. Similarly to Georgia Tech, the results are

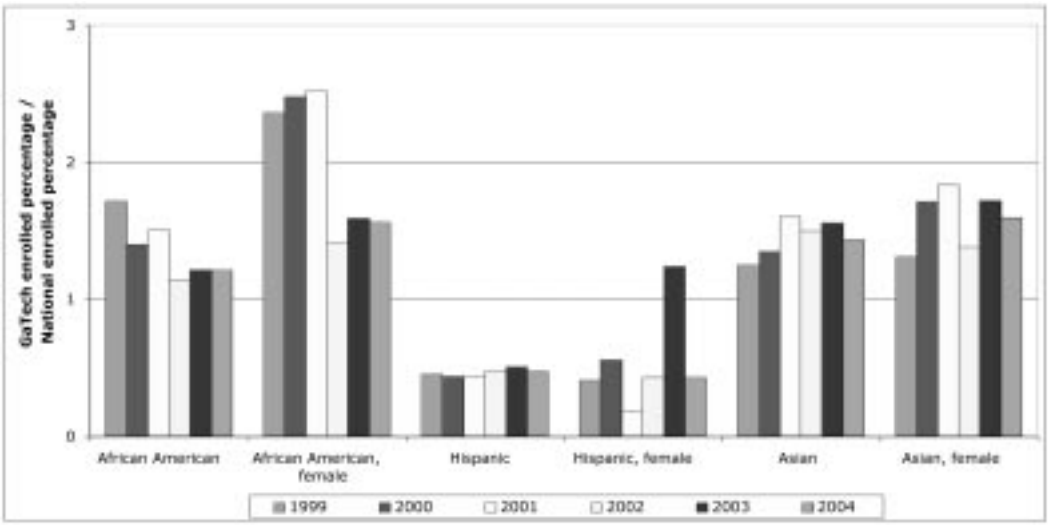


Fig. 5. Ratio of enrolled percentage in Georgia Tech's Mechanical Engineering Department and the National average enrolled percentage by ethnicity and gender from 1999– 2004. Data from responses sent by individual universities to the Engineering Workforce Commission (EWC) of the American Association of Engineering Societies from 1999– 2004 and collected through the authors' commissioned study by Engineering Trends, Houghton, Michigan.

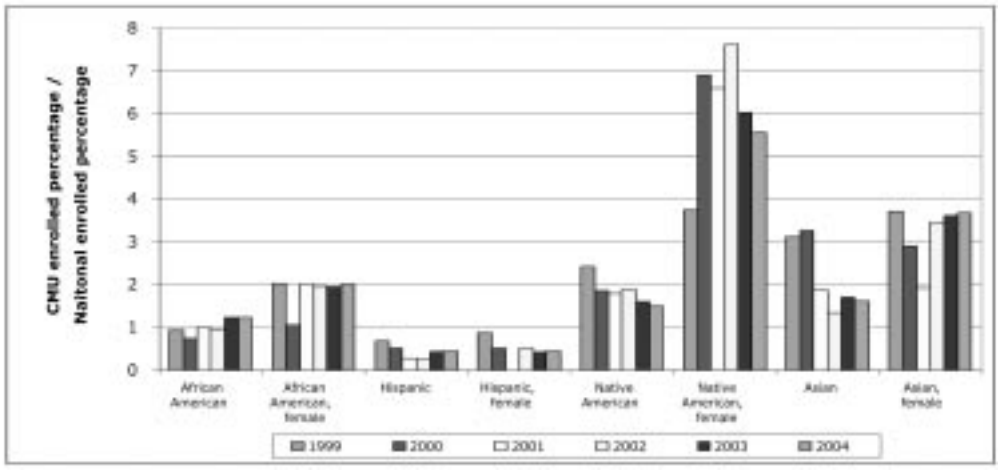


Fig. 6. Ratio of enrolled percentage in CMU's Civil Engineering Department and the national average enrolled percentage by ethnicity and gender from 1999–2004. Data from responses sent by individual universities to the Engineering Workforce Commission (EWC) of the American Association of Engineering Societies from 1999–2004 and collected through the authors' commissioned study by Engineering Trends, Houghton, Michigan.

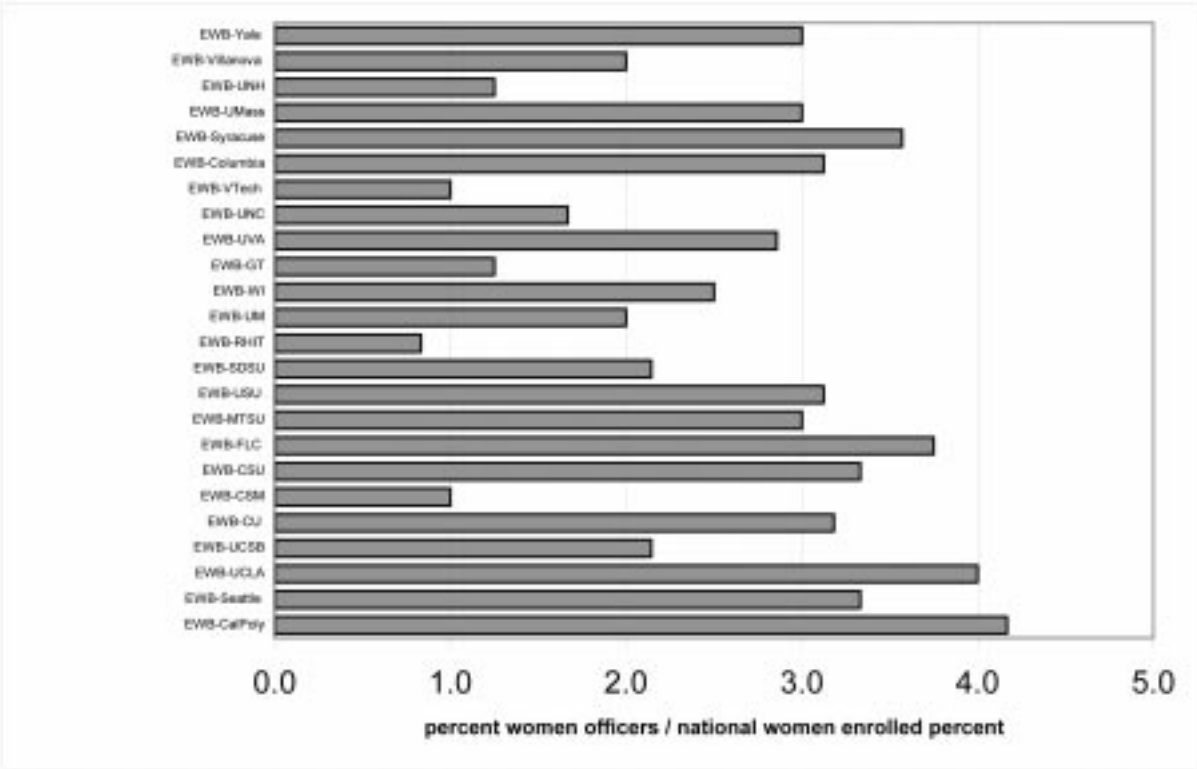


Fig. 7. Ratio of percentage of women in leadership positions within EWB student chapters and the National average of women enrolled in engineering disciplines in 2002 which was 20% [28] and the Engineers without Borders chapters are abbreviated as: EWB-CalPoly is California Polytechnic State University, San Luis Obispo, CA; EWB-Seattle is Seattle University, Seattle, WA; EWB-UCLA is University of California, Los Angeles, Los Angeles, CA; EWB-UCSB is University of California, Santa Barbara, Santa Barbara, CA; EWB-CU is the University of Colorado, Boulder, Boulder, CO; EWB-CSM is Colorado School of Mines, Golden, CO; EWB-FLC is Fort Lewis College, Durango, CO; EWB-MTSU is Montana State University, Bozeman, MT; EWB-USU is Utah State University, Logan, UT; EWB-SDSU is South Dakota State University, Brookings, SD; EWB-RHIT is Rose-Hulman Institute of Technology, Terre Haute, IN; EWB-UM is University of Michigan, Ann Arbor, MI; EWB-WI is University of Wisconsin, Madison, Wisconsin; EWB-GT is Georgia Institute of Technology, Atlanta, GA; EWB-UVA is University of Virginia, Charlottesville, VA; EWB-UNC is University of North Carolina, Chapel Hill, NC; EWB-VTech is Virginia Polytechnic Institute, Blacksburg, VA; EWB-Columbia is Columbia University, New York, NY; EWB-Syracuse is Syracuse University and SUNY Environmental Science and Forestry, NY; EWB-UMass is University of Massachusetts, Amherst, MA; EWB-UNH is University of New Hampshire, Durham, NH; EWB-Villanova is Villanova University, Villanova, PA; EWB-Yale is Yale University, New Haven, CT.

not conclusive because Hispanics, total and women, are generally underrepresented in the department despite this curriculum. There are, of course, other factors that play into a student's choice for a major and enrollment in particular college or university but further analysis could provide more insight into the significance of education for sustainability as a driver for a particular major area or institution.

The remaining case study is focused on the leadership of student chapters of Engineers without Borders. The mission of Engineers Without Borders (EWB-USA) is to partner with disadvantaged communities to improve their quality of life through implementation of environmentally and economically sustainable engineering projects, while developing internationally responsible engineering students. EWB recognizes the challenge of training a new generation of engineers who could better meet the challenges and needs of the developing world. The challenge is the education of engineers:

(i) who have the skills and tools appropriate to address the issues that our planet is facing today and is likely to face within the next 20 years;
(ii) who are aware of the needs of the developing world;
(iii) who can contribute to the relief of the endemic problems of poverty afflicting developing communities worldwide [27].

EWB is a chapter-based organization with student chapters at colleges and universities across the country encouraging students in SET disciplines to become actively engaged in sustainable development.

An analysis of the students who are involved in EWB chapters could provide additional insight into the demographics of students who are drawn to this type of service learning and contribution to sustainability. Even more important, perhaps, is providing a leadership opportunity within the student chapters to women and underrepresented groups. When an analysis on the leadership demographics within the EWB student chapters is conducted, the results indicate that women are more actively engaged in EWB and in leadership roles than would be suggested by the National average enrollment of women in engineering disciplines (Fig. 7). In the fact, the overwhelming majority of EWB chapters, 23 out of the 24 established chapters, have an equal or higher percentage of women in leadership positions when compared to the National average enrollment of women in engineering.

CONCLUSIONS

Given that the anecdotal evidence and individual case studies presented in this paper appear to support the hypothesis that education for sustainability can be used as a recruitment and retention tool for women and underrepresented groups in SET disciplines, the authors are currently leading a full study to determine the statistical significance of this correlation by collecting data that are not aggregating at the department level, as well as to determine the role that the opportunity for sustainability education and training plays in a student's determination of which institution to attend and major discipline. The research questions focus on establishing, both quantitatively and qualitatively, how to most effectively teach sustainability to maximize the diversity recruitment and retention benefits and, also, how to measure outcomes of this type of training. The anticipated results of this study will provide new insights that will enable educators and researchers to capitalize on the opportunity that sustainability presents to SET (shown in Fig. 2).

Specific research questions include:

- Recruitment—What are the attributes and characteristics of the research questions, problems, needs, opportunities, and desires stemming from the fundamental elements and dimensions of sustainability (shown in Fig. 1), that most appeal to women and underrepresented groups in SET disciplines, and which could be used in recruitment efforts?
- Retention and Development—What education and research mechanisms exist to enable women and underrepresented groups in SET disciplines to pursue these research questions, problems, needs, opportunities, and desires within both the formal education path and the service learning path, which could be used in retention and development efforts?
- Assessment—What indicators, metrics and tools exist to evaluate and assess the outcomes of this education and research effort, particularly in establishing the intellectual merit and broader impact of not only the answers, solutions, satisfaction, realization and fulfillment of the research questions, problems, needs, opportunities and desires pursued by women and underrepresented groups in SET disciplines, but more importantly, of using sustainability education to enable the increase of diversity in SET related disciplines?

Finally, a follow-up to the study will be to examine the path that these newly engaged individuals follow through undergraduate education to graduate school and into the workforce. For example, does the distribution of students hired by academia, industry, government or NGOs change with an SET education that is enhanced with sustainability awareness and training?

There are many challenges in terms of the importance of maintaining the SET workforce given its critical role to the future of the nation; indications are that this future workforce may not be assured. At the same time that science, engineering and technology are relied upon to increase

the nation's productivity and economic wellbeing, advance healthcare, improve the environment, help ensure national security and provide the knowledge for effective governance, there are signs that a sufficient workforce will require engaging those population segments that have not traditionally pursued SET related careers. In addition to maintaining the workforce, the increased diversity can serve to enhance the ability of SET to engage in advancing the goal of sustainability. There is some evidence which suggests that an academic environment offering opportunities in sustainability, through traditional or service learning paths, may be better at recruiting and retaining women and underrepresented groups to SET. The added advantage of training the future SET workforce in sustainability is that it will enhance their ability to design solutions that will benefit people, promote prosperity and protect the planet.

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Julie Beth Zimmerman is an Assistant Professor at Yale University with joint appointments in the Department of Chemical Engineering, Environmental Engineering Program and the School of Forestry and Environmental Studies. Julie also serves as the Assistant Director for Research at the Center for Green Chemistry and Green Engineering at Yale. Previously, she has served as an Assistant Professor at the University of Virginia in the

Civil Engineering department. She has also been a programme director in the Office of Research and Development, US Environmental Protection Agency. She is co-author of the *12 Principles of Green Engineering,* initiated EPA's P3 (People, Prosperity, and Planet) Award: A National Student Design Competition for Sustainability, and serves on the steering committee for the US Partnership for the UN Decade for Education for Sustainable Development. Her research and teaching interests include pollution prevention, green engineering, green chemistry and sustainability.

Jorge A. Vanegas recently joined the College of Architecture at Texas A&M University as director of the Centre for Housing and Urban Development (CHUD) and professor in the Department of Architecture. Before joining Texas A&M, he held faculty appointments in the School of Civil and Environmental Engineering at the Georgia Institute of Technology and in the School of Civil Engineering at Purdue University. He earned a B.S in architecture from Universidad de los Andes in Bogotá, Colombia, and holds M.S. and Ph.D. degrees from the Construction Engineering and Management Programme in the Department of Civil and Environmental Engineering at Stanford University.