Engaging Female and Underrepresented Community College Students through Humanitarian Engineering and Context Based Learning Pedagogies

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Abstract

It is a known fact that female and underrepresented ethnic groups (African American, Hispanic, Pacific Islanders and Native Indians) are scarce in Engineering Classrooms. These demographic groups also have rather high attrition rates on Engineering Courses. At Ohlone College, we found that Engineering for Humanitarian/Social Change classroom projects increased retention, commitment and academic success amongst female and ethnically underrepresented students. Our pedagogy is based on Context-Based Learning (CBL) Service Based Learning (SBL). Therefore, we discuss data collected over four semesters that suggests that the integration of Context-based learning (CBL) and Service based Learning(SBL) through Engineering for Humanitarian and Social Change projects, could indeed increase the number of female and ethnically underrepresented students in Engineering classrooms. We also discuss our NSF-UC Berkeley funded collaboration on Context-Based Learning and the IEEE Santa Clara Section's support for Engineering for Humanitarian and Social Change Projects at Ohlone College.

Female and Underrepresented Ethnic Group Students in Engineering

To continue advancement in energy science and research and to thrive in a global economy, the U.S. will have to rely on scientists and engineers to develop innovative and high-value-added products and services, as well as improve productivity through the use of technology-based tools.[1] This pipeline of scientists and engineers, with its under-representation of women and underrepresented minorities (African Americans, American Indians or Alaskan Natives, and Hispanic Americans), is a critical concern for the U.S.[2] In 2010, the National Academies of Science reported that underrepresented minorities "embody a vastly underused resource and a lost opportunity for meeting our nation's technology needs".[3] With today's society facing global challenges in energy that are essential to sustaining our current way of life, it is even more critical for 4-year institutions to reach out to pools of students traditionally underrepresented in science and engineering programs.

One pool of such students is community college students pursuing math, chemistry, and physics courses that are transferrable to baccalaureate programs. In a Strategy for American Innovation, the Obama administration stated that "President Obama is taking continuous steps to improve our educational system ... and to promote student achievement and careers in STEM fields", and "the Administration is committed to restoring America's global leadership in college graduation rates ...., making investments in community colleges ...."[4,5] With more resources being allocated to community colleges to stimulate student achievement in STEM fields, and community colleges serving many ethnic and racial minorities, community college students are uniquely positioned to fill the pipeline of STEM professionals.

With enrollment in the nation's community colleges hitting an all-time high, students from these institutions are a rich source of the nation's recipients of undergraduate and graduate degrees in STEM fields. The community college transfer pathway is particularly important for African American, Hispanic and Native American STEM degree recipients, as well as low-income students due to its low cost ($36/unit).[6] In this time of high unemployment and economic crisis, as in earlier recessions, community college enrollment has surged. During the 2009-2010 academic years, California alone enrolled 2.7 million students. The California Community College System (CCCS) is the largest community college system in the U.S., serving 25% of the nation's community college students.[7] Of the students enrolled for 2009-2010, 40% were from NSF-categorized underrepresented minority backgrounds. In fall 2009, nearly 50,000 CCCS students transferred to University of California (UC) or California State University (CSU) campuses[8]. One year earlier, nearly 20% (3,344) of all UC B.S. degrees in STEM fields were earned by community college transfer students, but only 11% (356) of these transfer graduates were from underrepresented minority backgrounds; 40% were women.[6] According to in 2015 fifty-five percent of community college students are people of diverse ethnic backgrounds and roughly 53 percent are female.[6]

Despite the relatively significant number of female and ethnic minority students in the CCCS we see a disproportionately low number in the STEM fields. Therefore, there is the need to adapt our classroom pedagogies to engage these demographic groups of students.

Context Based Learning Pedagogy

The Obama Administration has forecasted that over the next decade, the U.S. economy needs approximately 1 million more STEM professionals than the U.S. will produce at current rates.[9]

In February 2012, the President's Council of Advisors on Science and Technology (PCAST) issued an undergraduate STEM education report indicating fewer than 40% of students who enter college intending to major in a STEM field complete a STEM degree. Increasing the retention of STEM majors from 40% to 50% would alone generate three-quarters of the targeted 1 million additional STEM degrees over the next decade. With the first two years of college being the most critical years for the recruitment and retention of STEM majors, it is imperative to focus actions on methods that influence the quality of STEM faculty and adopt teaching methods supported by evidence derived from experimental learning research.

Research has found that high-performing students frequently cite uninspiring introductory courses as a factor in their choice to switch majors.[10] Empirical evidence about how people learn and assessment of outcomes in STEM classrooms all point to a need to improve teaching methods to enhance learning and student persistence.[10] However, a significant barrier to broad implementation of evidence-based teaching approaches is that most faculty lack experience using these methods and are unfamiliar with the vast body of research indicating their impact on learning. This gap in experience has resulted in STEM education lacking relevance to a student's life, where STEM classes traditionally teach sets of scientific and engineering principles and concepts with little course time devoted to exploring the application of principles and concepts in real-world context or technology implications.[11] Additionally, scientific principles are typically taught in scientific discipline silos, without real-world application that can span more than one scientific discipline.

Responding to the challenges identified in the PCAST report, UC Berkeley created a research experience program for community college faculty, called **RET in Engineering and Computer Science Site: UC Berkeley's Context-Based Research Experience for Community College Faculty** *(also referenced as the UCB Context-Based RET Site in this article)* that offered community college faculty a nine-week experience that integrated individual hands-on research with team-based curriculum development to enable new research concepts to be introduced in community college classrooms in the *context-based approach*. Closely aligned with project-based learning and inquiry-based science education, the context-based approach was selected to provide the participants a pedagogical method that brings their research experience alive in the community college classroom by tying the teaching with applications that students can relate to in their lives.[12] The *context-based approach* has been shown through assessments to enhance the students' interest in STEM and has been applied successfully in college teaching, particularly to the teaching of chemistry[10,12]. Empirical evidence has also shown that context-based education helps students see and appreciate more clearly the links between science and everyday lives.[13,14,15] The context selected for this RET program was technology applications that offer societal benefits and have employment opportunity potential. The premise is that using such context will increase community college student engagement in STEM studies, thereby contributing to student persistence and eventually, improved retention rates of students in STEM.

RET NSF-UC Berkeley Funded Collaboration on Context-Based Learning

The primary goal of the UCB Context-Based RET Site was to provide a professional development experience for community college faculty that:

- Engages community college faculty in research of current engineering topics;
- Promotes literacy in applications of their research topics;
- Guides faculty to develop and teach context-based science and engineering lessons that connect science and engineering concepts to practical applications;
- Enables community college students to connect their STEM education to exciting careers;
- Builds a vibrant network of community college faculty, faculty, postdoctoral, and graduate student researchers that results in long-term collaborative partnerships; and
- Disseminates online context-based training modules that can contribute to the scientific and engineering literary of community college faculty and the general public.

To deliver on these goal and objectives, the UCB Context-Based RET Site was a nine-week summer experience, consisting of three elements: independent research, team-based curriculum development, and professional development seminars. The UCB Context-Based RET Site was based on a context-based model, where the *context* is a technology application, rather than a focus on a particular research concept.

Program Design: During the summer program, 4 community college faculty participated in a 9-week experience, with 8 weeks focused on research, and 1 week focused on curriculum development. Each faculty's experience consisted of three elements:

<u>Independent Research</u>: Each community college faculty member conducted an independent 8-week research project in an engineering research group in which faculty, postdoctoral researchers, and graduate students were involved in existing research.

<u>Team-based Curriculum Development:</u> The community college faculty designed and developed teaching modules that linked the technology focus area with the concepts from the research of each team member. The design and some development activities for the teaching modules ran concurrent with research. The faculty transitioned into fulltime curriculum development during the ninth week of their fellowship. UC Berkeley's Center for Teaching and Learning also supported the faculty in the design and development of the teaching modules.

<u>Professional Development:</u> Community college faculty participated in a research orientation, training in research protocol, laboratory safety, and scientific ethics, group meetings, and seminars on context-based pedagogical methods and online education.

Together, this breadth of summer experience made this a broad learning experience that took full advantage of the strengths of the university.

Green and Sustainability Manufacturing

Manufacturing is an unlikely first choice for a profession among college students. Nevertheless, in the 2012 State of the Union address, President Obama gave a blueprint for an economy that is built to last based on American manufacturing.[16] The manufacturing sector has driven knowledge production and innovation in the U.S. by supporting two-thirds of private sector research and development and by employing scientists, engineers, and technicians to invent new products and introduce innovations in existing industries[17]. After several decades of decline, early signs of manufacturing returning to the U.S. reflect the changing of conditions.[18,19,20] Resurgence will only be realized with sustained cost competitiveness and innovation. Reducing environmental impact, utilizing resources more efficiently and, overall, greening the technology of production are elements in lean manufacturing. At many levels, substantial process improvements can be made to reduce energy and resource consumption. But there is also potential in manufacturing enhancements that have a larger impact on the life cycle impact of the product the manufactured item is used in. This is referred to as leveraging and identifies manufacturing-based efficiencies in the product that are due to improved manufacturing capability but which, in the long run, have their biggest effects on the lifetime consumption of energy or other resources or environmental impacts.

Community college faculty participating in the green and sustainability manufacturing topic will learn how design and manufacturing practice can influence sustainability, including analysis of process and system effects and consider the social impacts of manufacturing. Specific topics for research projects included:

- Defining metrics for sustainability in manufacturing
- Green supply chains
- Linking social impacts to design and manufacturing decision-making
- Material selection (green chemistry and materials) in manufacturing
- Case studies in green manufacturing practice

Pedagogy of Humanitarian Engineering in the Introduction to Engineering Class

Engineering education could be said to be at a crossroad, with educators and researchers calling for new ways to understand engineering's social role. Two approaches to engineering education that are relevant to the social context of engineering have emerged. First, there is a growing trend for engineering education to address issues of human development. Vesilind suggests that, historically, engineers have been employed as "hired guns, doing the bidding of both political rulers and wealthy corporations[21]. However, he says, there is a new kind of engineering emerging, one “rooted in the greater ideas and aspirations of engineering as a service to all humanity.”[21] Robbins also predicts that we are at the beginning of an emerging field in engineering.[22] Second, there is a need to embed globalization within the engineering curriculum to provide students with the knowledge and skills to respond to globalization issues and to work in a global context. The importance of globalization of the engineering curriculum has been highlighted by various researchers. Some of these researchers suggest that showcasing engineering within a global context is necessary for global competitiveness, cultural inclusivity, and sustainable design.[23,24,25]

Vandersten closely links presenting engineering in a global context to the humanitarian engineering pedagogy.[26]

Humanitarian Engineering (HE)

According to, Humanitarian Engineering (HE) as a discipline was founded in 2003, when the William and Flora Hewlett Foundation funded the creation of a minor program at Colorado School of Mines (CSM).[27] Muñoz describes the new discipline as “a wave that’s passing through the world among young people that are bent on trying to improve the lives of humans on the planet in a sustainable way.”[28]

Though Munoz describes humanitarian engineering as a discipline and established it as a full program at the School of Mines, this paper showcases the integration of humanitarian engineering an existing engineering course/curriculum.[27] The argument is made that where having humanitarian engineering as a program may be challenging due to time and resource constraints, Colleges can integrate humanitarian engineering in already existing courses. This integration provides students the opportunities to be globally competitive, but more so to better appreciate cultural diversity which has a boomerang effect on creating an inclusive learning environment for female and underrepresented students in Engineering.

Burnham highlights that compared to other professions, Engineers seems to have immense power and responsibility and should therefore be afforded the opportunities to channel this desire for positive change around the world.[29] Engineering Education should therefore prepare students to make lasting positive impact in the lives of people globally.

Munoz also defines Humanitarian Engineers as Engineers who “try to balance technical excellence, economic feasibility, ethical maturity, and cultural sensitivity” through a set of specially designed technical, humanities, and social science classes, as well as a Design Experience.[30] This could arguably be said to really be the definition of an engineer, not just a humanitarian engineer.

Munoz also went further and defined the Humanitarian Engineering Program by breaking down the definition as:

"Humanitarian: an artifact, process, system, or practice promoting present and future wellbeing for the direct benefit of underserved populations."[31]

"Engineering: designing and creating a component, subsystem, or system under physical, political, cultural, ethical, legal, environmental, and economic constraints."[31]

"Humanitarian engineering: design under constraints to directly improve the wellbeing of underserved populations."[31]

HE seeks to augment technical engineering expertise with understanding of the social, political, and economic realities that define the systems in which engineers live, work, and for which they design solutions.[29] HE looks to address, in a comprehensive way, the needs of students, faculty, industry, the global community, and governmental as well as non- governmental organizations, to work toward solutions to the basic problems plaguing the human experience on earth.[32]

Humanitarian Engineering is quite popular with many engineering students, as there is a need for the students to see that their future work or career would contribute to making a positive impact in the world. In many US universities, there is an increase in student interest in service learning, community engagement, and global issues, with undergraduate and graduate programs developing to support this interest.[33] Claes Helgesson notes that, "many engineering students and professional engineers are frustrated at being tied up with solving problems connected to people in the wealthy part of the world."[34] This new movement towards active social responsibility in engineering has a desire to ensure that products, systems and processes designed by engineers are not just meeting functional standards but are also meeting societal standards.

HE similar to context based learning pedagogy helps the student contextualize their work, see the direct value and applications, create accurate mental models and as such become intrinsically motivated to pursue their engineering education. This popularity of HE is even more evident amongst female and underrepresented students.

Various researches suggest that one of the most important plus of Humanitarian Engineering is that it can attract and engage a more diverse pool of individuals.[35] There is a growing understanding that, for women and for students from some underrepresented groups, a major factor in career choice has to do with making a difference.[35] "This has not been a widespread image—engineers as members of one of the 'caring professions.' But it's an image that we can build, both for our students and for the community as a whole."[36]

A number of Colleges with HE programs are beginning to see greater diversity in their engineering cohort of students. Purdue and Colorado School of Mines have reported that over twice the percentage of women are interested in HE than in the average engineering department.[37] This is encouraging news given the fact that "the U.S., as a nation, has made no progress in diversifying engineering in some key dimensions."[38]

Through showcasing the ideas of HE, engineering schools can attract more minorities, such as women and non-technically oriented students, pushing diversity in engineering to new levels, and widening the range of perspectives needed to solve problems. The concepts at the core of the Humanitarian Engineering (HE) movement are not utopian fantasies, but rather a realistic analysis of where engineering has been, where it is now, where it is heading, and what engineering students need to learn today in order to be prepared for the future.[38]

Ohlone College Engineering for Female and Underrepresented Students (EFUS) Project through the Introduction to Engineering Course

Research has shown that the need to nurture in female students is one of the reasons why they pursue careers in healthcare and the arts. Hence the EFUS project aims to provide the opportunity for female students to 'nurture' through engineering and as such engage them in seeing that engineering provides a lot of opportunities to create solutions that 'nurture'. Engineering for Humanitarian needs will likewise create the feeling of being valuable and relevant in solving problems around the world, as gain research has shown that being valuable is important for underrepresented students to stay engaged in a course/career.

The EFUS project was first implemented in the Spring Semester of 2014. The IEEE-CPMT/SCV funded the project with $2500, donated to the Ohlone College Foundation. The project was embedded into the Introduction to Engineering Course, which has the flexibility and scope to support the EFUS Project. Students were very excited and motivated just to hear that their course/project is being supported by the IEEE-CPMT/SCV, it gave them a sense of belonging to a larger community of Engineers and also made them feel valued. This in no small way was instrumental to the intrinsic motivation evidenced by all the students on the course while facing design and team work challenges during their projects.

The project gave the students a taste real life Engineering as they went through the whole Engineering Design cycle and Problem Solving Sequence on their respective projects. The female and underrepresented students in the class where motivated to take on leadership roles in their teams and contributed to identifying humanitarian needs in the world and formulating probable solutions. Furthermore the female and underrepresented students felt valued and had a sense of purpose as they saw how they could change the world positively and engage in a good cause through engineering (this was particularly true for the female students).

Many of the students from underrepresented ethnic groups felt valued as they identified and discussed humanitarian needs that they or a family member or friend was experiencing/had experienced. They also highlighted to their team mates the appropriate technologies that could be used to solve those humanitarian problems. Feedback from the students concerning the EFUS Project was very positive. Here are some quick statistics from the students' feedback.

- 100% of the students felt that the EFUS project had motivated them to stay on course with their Engineering Education and Careers.
- 100% of the Female students mentioned that through the Project they saw how they could change the world positively through Engineering.
- 100% of students who were undecided about Engineering as a career (at the beginning of the semester), decided to commit themselves to an Engineering Education (80% of the female students decided to take summer math classes to speed up their Engineering Education).

The students also presented their Projects at the Ohlone STEM day on May 9, 2014 to 60 Middle School Students. This had a domino effect as many of the middle school students were very interested in the projects and wanted to design and build the sort of prototypes they saw. The EFUS Project students felt a sense a fulfillment as they were also engaged in the process of encouraging the next generation of Engineers, through Service Learning. The EFUS project also featured the June edition of the Tri-City Newspaper (http://www.tricityvoice.com/displayPages.php?issue=2014-06-24&page=5)

Implementing the RET UC Berkeley Experience in the Introduction Engineering Course at Ohlone College

The RET experience was an invaluable experience that supported the pedagogical methodologies of humanitarian Engineering and Context Based Learning. Community College Faculty engaged in research on Sustainable Manufacturing which was easily embedded in the Introduction to Engineering Course as a topic under Engineering Ethics and Engineering Design. Students had to include different aspects of sustainability in their Capstone Projects which was underlined by humanitarian engineering theme. The research experience at UC Berkeley provided Faculty with an in depth understanding of global sustainability issues which faculty discussed in the class room and provided students with a better understanding of these issues.

Again the retention of female and underrepresented students is significant as many have made a commitment to engineering as a career. Feedback from some students were;

"The Humanitarian Engineering Project really made me see the difference I can make as an Engineer;"

"I now see that Engineering is also about caring for the world- which I really want to be part of."

"My opinions as a female student were valued as we had to really understand the social injustice that people face- somehow my team of male students valued my contribution and I took leadership role".

In conclusion this paper highlights the role that humanitarian engineering and context based learning has in retaining/increasing the number of female and underrepresented students and shows how HE can be effectively incorporated in the Engineering Curriculum via the Introduction to Engineering Course. This paper also highlights the importance of Programs like the UC Berkeley RET program for Community College Faculty in propagating HE and CBL.

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