STEM Energy Education in California San Juaquin valley (Work in Progress)

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Since 2012, Christopher Butler has served as the Assistant Director of the Engineering Service Learning program at the University of California, Merced. In this time as Assistant Director, the Engineering Service Learning program has provided design experience to more than 1,800 students, completed over 15 community facing engineering student-lead projects, and produced more than 200,000 community service hours. Butler brings faculty and industry partners together to mentor and support these student projects as students gain real-world experiences the necessary skills for future careers.

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Background

There are significant educational equity gaps that exist in STEM fields for underrepresented minority (URM) students who live in the San Joaquin Valley. URM students are defined as non-white and non-Asian, though it is recognized that there are subpopulations of URM students within each of these non-URM groups, and ethnicity is not always easily defined. Some of these equity gaps present themselves as differences in academic achievement between underrepresented minority URM students and non-URM students or women in STEM fields and arise due to numerous academic and social factors. Significant factors for attrition are perceptions about careers in the STEM fields, poor experiences with the academic culture and teaching pedagogy, and declining confidence due to demanding curriculum. One study shows that students without early exposure to real-world applications of their major, that give positive insight into potential careers, do not always connect with upper-classmen to use as successful peer role models. This research has shown that access to peer role models increases academic persistence [1], [2]. It has also been shown that retention of URM and women is increased through project-based learning or experiential learning pedagogies and techniques[3]-[10].

Moreover, URM students often have a limited perspective of their contributions to improving technology due to social issues such as a lack of exposure to engineering and science professions and having personal role models in their local community who are scientists or engineers. Furthermore, when URM students enter STEM fields, many fail to see the connection between their studies and real-world problems because gateway courses in current curricula fail to make that connection explicit [10], [11].

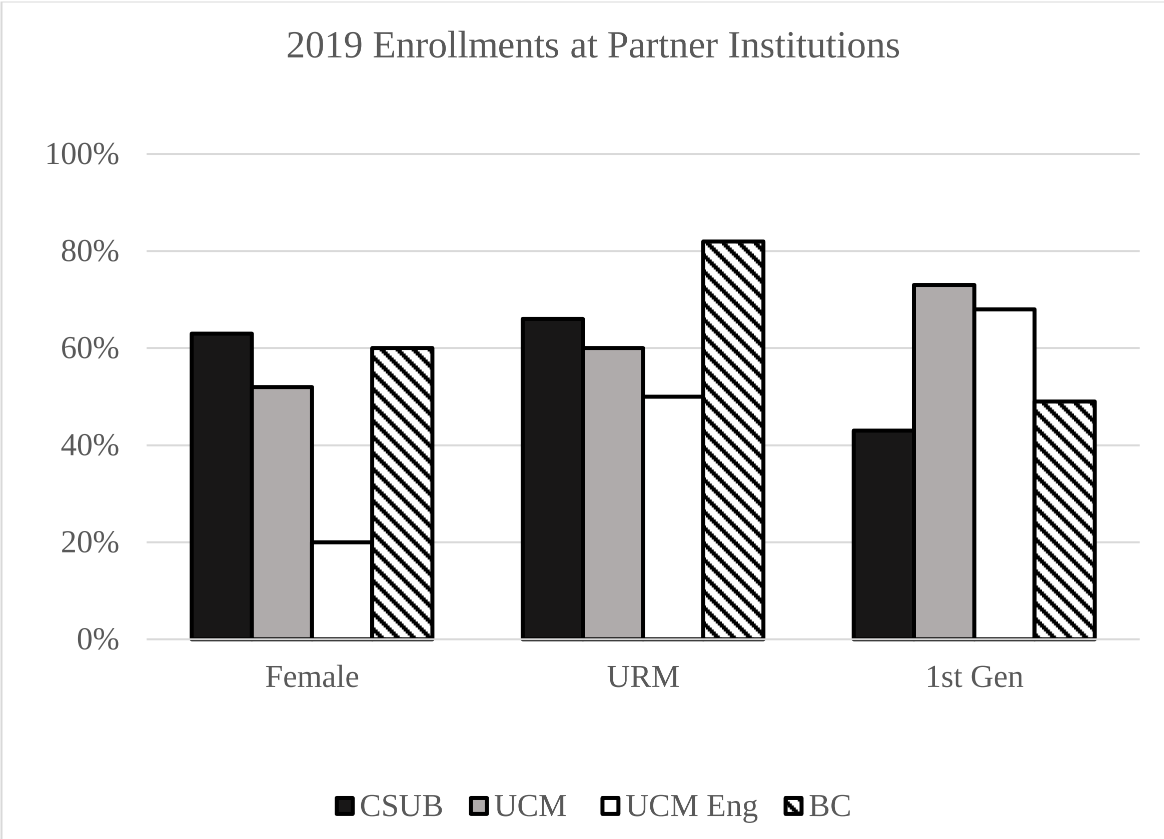

Figure 1: Student Demographics in the San Joaquin Valley

As shown in Figure 1, female and URM student populations at the partner campuses are measurably higher as compared to the national statistics (25% and 26%, respectively). Each partner campus shows high numbers of enrolled URMs, 60%, 66%, and 82%, respectively. These high enrollments of URMs, have resulted in Hispanic Serving Institution designations and are representative of the ethnic makeup of the region. In addition to high rates of female and URM enrolments, the University of California, Merced, California State University, Bakersfield (CSUB) have percentages of 1st-generation enrollments 73%, and 43%, respectively.

Within the San Joaquin Valley, the engineering enrollment demographics are more pronounced than the national averages. While female enrollments are on par with national enrollments, URM percentages are 50% higher than the national averages for the partner universities. These students are more likely to experience equity gaps that result in slower progress towards degree attainment, retention within their chosen major, and career preparation.

Methods

As stated in the [13], over the next three years, each of the three partner campuses will focus on reducing equity gaps faced by our unique student populations through the implementation of two pedagogies in introductory gateway courses within the chemistry and engineering disciplines. At the UC Merced, an entry-level human-centered engineering design course will be created utilizing a Flipped Classroom (FC) pedagogy. At CSUB and Bakersfield College (BC), the general chemistry courses will employ a Flipped Classroom Enhanced-POGIL or (FC-E-POGIL) pedagogy. This work in progress study anticipates utilizing pedagogical advancements in engineering design and chemistry to close equity gaps by addressing these project outcomes of increasing retention in a chosen or declared major, improving progress towards graduation, and improving career preparedness among our students.

Typical structures for flipped classrooms involve assigning students to view a video of lectures or use distance teaching software before the in-class period, which provides the foundation of the students' knowledge on the subject matter [14]. Active learning takes place during in-class periods to solidify the topic material and then followed-up with homework assignments [15]. Flipped classroom pedagogies increase the expectations placed on the student and the teacher [16] by first, creating an expectation that students complete tasks at home that are not "just for a grade"; these pre-class videos are inherently pivotal in learning the material. Moreover, this expectation places an increased responsibility for learning on the student [17]. Second, there is an expectation for the instructor to set clear goals for the student and gathers or prepares a large amount of material for the students' consumption.

A more specific pedagogy of flipped classroom, Process Oriented Guided Inquiry Learning (POGIL) [18], [19] includes a formalized approach to in-class activities, which involves the assignment of student roles for in-class activities, including a Manager, Reader, Analyst and Ambassador during the in-class period. Students rotate the roles to allow each member of the group to have the opportunity to lead, record, and report [19]. Instead of being the sole source of knowledge communication, the instructor facilitates these teams with helpful guidance as students work through structured content that provides information, questions, and challenges that lead students through inquiry to achieve learning. The process and the structure of the teams guarantee active learning and critical thinking from all team members. Through the implementation of the FC, and FC-E-POGIL pedagogies, the partner campuses will tailor to the various learning styles to these unique gateways STEM courses. According to the VARK (visual, aural, reading, and writing, kinesthetic) learning style inventory, both pedagogies engage multiple learning styles to increase the engagement of each student [20], [21].

Flipped classroom pedagogies, including POGIL, effectiveness on student outcomes has been demonstrated thoroughly in the literature through longitudinal studies [22], STEM classes [17], [23], and quantitative studies of exam performance [24]-[29]. The literature shows increases in student outcomes, student perceptions [14], even in self-efficacy with regards to complicated subject matter [29]. The flipped classroom pedagogy equalizes opportunities for students, especially for students of lower socioeconomic status and first-generation students. In comparison to advantaged students who may have support systems in place to help complete homework and projects with tutors or advice from previous generations of how to navigate higher education, disadvantaged students are able to take advantage of the relocation of the homework and projects inside the classroom and benefit from interaction with the professor in the classroom. The flipped class allows both subsets of students to complete their in-class learning with the support of experts in these fields [30].

As stated previously, URM's including women, show increased retention in STEM and Engineering fields when they can connect their direction of study with real-world applications. To this effect, first-year engineering students at UC Merced participate in an introductory design lecture course called Human-Centered Research and Design (HCRD) that uses the FC pedagogy beginning in the fall 2020 semester. The HCRD lecture course will serve as a gateway and cornerstone engineering design course that will introduce human-centered design concepts in applied scenarios. Modeled after the successful Engineering Service Learning course at UC Merced, the students in the HCRD course will be open to all majors at the university, both engineering and non-engineering. Design concepts such as problem identification, stakeholder and context development, specification development and market analysis, iterative prototyping and evaluation, collaborative writing, client interactions, ethics and other topics will be covered. Online videos with accompanying quizzes will assess the subject matter understanding of the students. In-class discussions will be conducted with students with real-world examples of the application of each design principle or skill, followed by related homework assignments. Reflections questions will be provided each week through written prompts to allow students to make connections between the subject matter, real-world examples, and the impacts of these examples and the students can have professionally on their communities. In place of a final exam, small-group (2-4 students) research projects will be conducted and presented by students related to energy and other large-impact engineering fields to encapsulate the design process with relatable scenarios. The student groups will be provided with one of two initial scenarios that impact large regions and communities in California in the areas of water supply and power distribution to small communities. Through each research study, students will consider the needs of the community being served in addition to the social, environmental, economic, and technical impacts or considerations of the project after delivery.

Students at the two south valley campuses will participate in an FC-E-POGIL general chemistry course to improve retention. Students will provide input on whether the process-oriented approach, with defined roles for in-class activities, increased their learning. Implementation and assessment methods will be developed, such as student surveys, online learning modules, and a tool-kit to support faculty implementation of FC-E-POGIL to their classrooms.

Typically in FC or active learning classrooms, improvements in student learning have been measured through the use of student surveys and improved student passing rates [18]. Within the HCRD course, various methods to ensure student knowledge gains and perceptions towards their career preparedness and progress towards degree completion will be assessed through pre and post-semester surveys, reflections, and final exam/presentation scores. At the two south valley campuses, students will be primarily be assessed to identify the length to which FC-E-POGIL pedagogy is successful in improving knowledge gains. The impact of the two pedagogies on knowledge gains will be evaluated by conducting a one-way repeated measure analysis of variance (ANOVA). The ANOVA analysis will assess the difference in participants' summative knowledge gains based on final exams and presentations as the summative assessment method at each respective campus. Institutional data on student's majors and progress towards graduation and will indicate if participation in these courses helps meet project outcomes. At each partner campus, the effect on students' learning outcomes will be evaluated as each pedagogy is implemented in subsequent semesters over the course of the study and will identify if knowledge gains are increased by the pedagogy modifications and will ultimately reduce equity gaps.

Expected Results

Based on the findings over the course of the three-year study, the project team will be able to make recommendations on how to implement their findings as well as best practices. It is anticipated that the pedagogical changes will show increased program outcomes in terms of improved knowledge gains, and self-efficacy which will lead to increased progress towards degree attainment, retention within their chosen major, and greater levels of career preparation.

Significance

URM students will increase their self of belonging to STEM professions and begin to see a career/workforce pathway. Empowerments such as these have shown to increase student retention within a major and have positive self-efficacy impacts [31], [32]. Based on the shifting trends in STEM student demographics (**Error! Reference source not found.**), changes in STEM education and specifically, engineering education, will be required to ensure the retention of underrepresented minorities and women in these fields. Based on the results of this three-year study, best-practices will be identified and presented to allow for implementation at other universities.

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