Promoting Sustainability in Engineering Through EPICS Program

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Abstract* - Future engineers must be able to incorporate sustainability into all aspects of their designs to meet the increasing demands for the world's resources. Consequently, engineering educators have been challenged to integrate sustainability into existing curricula. Sustainability is a particularly complex problem requiring innovation, which often stems from diversity. Service learning programs have been shown to be an attractive and effective method to blend sustainability into engineering education curricula while also encouraging diversity in engineering. In particular, Engineering Projects in Community Service (EPICS) is a well-established service-learning program at 24 universities that has been known to accomplish this by presenting engineering in social context and engaging students in designing solutions to real world problems. This paper describes the complex problem of sustainability and its relationship with diversity and student attitudes in engineering, demonstrates the EPICS program's ability to promote sustainability and diversity in engineering, presents a research plan to evaluate its effectiveness, and provides preliminary results.

Keywords—Service Learning, Engineering Education, Sustainability, Diversity in Engineering, Native American engineering students

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Abstract–

Future engineers must be able to incorporate sustainability into all aspects of their designs to meet the increasing demands for the world's resources. Consequently, engineering educators have been challenged to integrate sustainability into existing curricula. Sustainability is a particularly complex problem requiring innovation, which often stems from diversity. Service learning programs have been shown to be an attractive and effective method to blend sustainability into engineering education curricula while also encouraging diversity in engineering. In particular, Engineering Projects in Community Service (EPICS) is a well-established service-learning program at 24 universities that has been known to accomplish this by presenting engineering in social context and engaging students in designing solutions to real world problems. This paper describes the complex problem of sustainability and its relationship with diversity and student attitudes in engineering, demonstrates the EPICS program's ability to promote sustainability and diversity in engineering, presents a research plan to evaluate its effectiveness, and provides preliminary results.

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I. INTRODUCTION

Sustainability and the interrelations between its environmental, economic, and societal aspects are very complex. In order to design sustainably, engineers must be aware that sustainable solutions require much consideration beyond the technical design and must also incorporate the cultural, social, ecological, and economic concerns among others. To produce engineers capable of these holistic sustainable designs, an engineering curriculum that contains well-integrated sustainability components must be developed. This has been stressed in multiple reports on educating future engineers including The Engineer of 2020 [1], Educating the Engineer of 2020 [2], the Civil Engineering Body of Knowledge [3], and the Accreditation Board for Engineering and Technology (ABET) Civil Engineering Program Criteria [4]. Engineering educators have approached this challenge in various ways from creating new courses dedicated wholly to sustainability to dispersing sustainability content throughout existing courses; however, many departments lack the funding or time for significant curriculum changes [5].

It has been shown that courses that apply a more "community-oriented and constructive, active learning pedagogical approach" particularly increase students' knowledge of sustainability [6]. This approach can be employed through service learning courses that allow students and faculty to experience the impact of designs on society first hand. Service learning projects allow societal impact to be integrated with technical problem solving, addressing the demand for more engaged, socially aware engineers. Past studies focused on service learning have shown that pedagogies that actively engage students in project based service learning effectively increase the number of holistic problem solvers [7, 8, 9, 10].

Integrating the needs of those affected by the design into the design process has been commonly identified as a key component of sustainable design. Stakeholder participation is required to adequately incorporate social and cultural values [11, 12, 13] which is a difficult task for both professional engineers and engineering educators. Ideally, concepts such as learning to listen to stakeholders and considering societal impacts should be incorporated into engineering design curriculum as a critical part of sustainability.

A focus on sustainability has been shown to increase diversity in engineering fields, through engagement of women and other underrepresented groups [14]. Additionally, it is well known that diversity in perspectives can help to foster the type innovation needed for sustainability [11]. Therefore design projects with a sustainability emphasis and stakeholder participation can simultaneously achieve multiple engineering educational goals.

Engineering Projects in Community Service (EPICS) is an example of a service learning program that has successfully met these goals. The EPICS program simultaneously incorporates sustainability into a

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multidisciplinary design course, both of which are necessary to make significant progress towards integrating sustainability in engineering [5].

This paper describes the complex problem of sustainability and its relationship with diversity and student attitudes in engineering, demonstrates the EPICS program's ability to promote sustainability and diversity in engineering, presents a research plan to evaluate its effectiveness, and provides preliminary results.

II. COMPLEX PROBLEM OF SUSTAINABILITY

Sustainability is a particularly complex problem. The U.S. Environmental Protection Agency defines sustainability as the ability to maintain or improve standards of living without depleting natural resources for future generations. The 1969 National Environmental Policy Act contains a continuing policy for the maintenance of "conditions under which [humans] and nature can exist in productive harmony, and fulfill the social, economic and other requirements of present and future generations of Americans." Sustainability is generally considered in terms of the interdependence among three systems: economy, society, and the environment. As such, pursuing sustainable solutions requires not only the optimization of all three systems, but also the optimization of systems across time, promoting equity now and in the future [15].

A common pitfall of current approaches to sustainability is over-emphasis of the environmental component and the lack of integrating the social and economic components with the environmental component. Little et al [16] uses the example of a polluted river that not only requires technical fixes such as source control, but also a shift in values, awareness, and culture to make the river completely sustainable. The components of sustainability cannot be evaluated independently but rather must be evaluated together. Enhancing sustainability is proving to be a difficult challenge due to these interrelations [16]. Furthermore, not only are the components interrelated and interdependent, but each is also complex as an individual system. The environmental system can include many factors such as energy, air, land, ocean, climate, and forest among others while the economic system encompasses factors such as mining, transportation, urban environment, and individual response. The social system is arguably the most complex with a clear emphasis on intergenerational equality that also encompasses the wide range of topics of poverty reduction, human, labor, and indigenous rights, socially responsible businesses, and sustainable product life cycles [16]. Because economic and social impacts are difficult to define, it is a challenge to determine the extent to which each component should be considered.

Due to these complexities, various approaches to sustainability have often been over-simplified for ease of understanding. Unfortunately, this has led to solutions that have failed or caused unintended consequences. Little used the case of biofuels, where policy makers only focused on the supply side of the problem and overlooked the fact that policies that encourage the use of biofuels may lead to unsustainable burning of resources and food among other potential side effects [16]. Unfortunately, unintended side effects can be hard to avoid when designing solutions for complex problems. For this reason, there is a stated need for more comprehensive solutions to address sustainability. This can be accomplished with a holistic or systems approach that accounts for the interactive nature of the environmental, economic, and social systems within sustainability.

Additionally, it has been noted that "the field of sustainability is largely fragmented" in more than one way. Although many different approaches to the sustainability problem currently exist, there is no connection between them. Current approaches tend to be either top down or bottom up, design principle based or computational, with no bridge between the methods. Additionally, there is a lack of interdisciplinary collaboration [16]. Consequently, it has been noted that new educational systems will be necessary to improve both the overall approach to sustainability and the interdisciplinary collaboration within the field. Particularly educational approaches that focus on introducing engineers to the holistic or systems way of thinking may beneficial [16].

III. SUSTAINABILITY, DIVERSITY, AND STUDENT ATTITUDES

Developing sustainability solutions requires collaboration among diverse backgrounds. At same time, women and other underrepresented groups may be attracted to a sustainability focus in engineering fields [14]. Therefore, courses on sustainability may be mutually beneficial for the field of sustainability and diversity in engineering. Furthermore, it is well known that diversity in perspectives can help to foster innovation [11]. Unfortunately, engineering and STEM fields typically lack this essential diversity in gender, culture, and/or thinking style. Furthermore, literature suggests that there is a disconnect between the traditional engineering curricula and diverse thinking styles that may contribute to low retention in engineering programs [17, 18]. Traditional engineering curricula do not engage students with diverse thinking styles outside that of "typical" engineering students, who tend to be analytical. Typology, the technical term for thinking style, is an effective and quantifiable measurement that gives an indication of student intellectual development and whole brain thinking, which are both necessary to educate engineers for the future [19].

The Hermann Brain Dominance Index (HBDI) is one of the evaluation tools that has been commonly applied for quantifying student typology. In the HBDI test, the blue quadrant represents analytical, the yellow represents conceptual, the green represents details and logistics, and the red represents collaborative and empathetic. Past studies using the HBDI have shown that a group of freshman and senior students will have distinctly different typologies, shifting "from a greater diversity of thinking styles in freshman to primarily the analytical thinking style for graduating seniors" as shown in Fig. 1 [19]. This shift may be caused by a loss of diverse thinkers or by individuals changing thinking styles throughout their engineering education.

Additionally, literature shows that there is a significant difference between thinking styles of male and female engineers. Fig. 2 shows that that the average typology for women is skewed downward and to the right when compared to men. Consequently, without a social context, such as sustainability, women may be less likely to persist in an engineering curriculum [19]. This may potentially also be true for other underrepresented groups.

It is also interesting to note that the same study showed that the industrial engineering program, known to be a less traditional engineering program with a strong focus on intellectual diversity, did not show the shift in typology between first year students and graduating seniors while also achieving an above average (38%) participation by women. The EPICS programs may see similar results as non-traditional program that also places more emphasis on intellectual development.

Furthermore, it is important for engineering educators to understanding student's beliefs about engineering and the standard engineering curriculum as well as the difficulties in challenging those beliefs [17]. Student attitudes towards

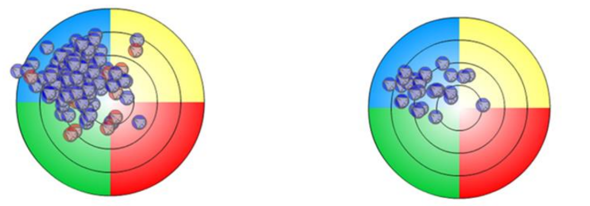

Fig. 1. HBDI data for first year and graduating seniors in traditional major. Blue circles represent men and red circles represent women [19].

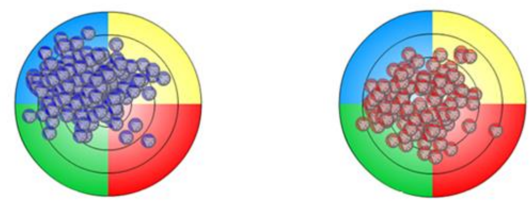

Fig. 2. HBDI data for industrial engineering students in 2008-2016 by gender [19].

sustainability, social awareness, and stakeholder involvement in engineering practices will be particularly important to understand for the EPICS program. Literature suggests that student engagement can not only have a significant impact on student retention but can also significantly impact student attitudes [17, 20]. Past studies have evaluated the effect on student attitudes of lecture series about the global and societal impact of engineering. In these studies, students showed a statistically significant increase from pre-survey to post-survey in their awareness of how engineers contributed to society [21, 22]. Similarly, EPICS should improve student attitudes towards sustainability, social awareness, and stakeholder involvement by exposing students to design projects with heavy emphasis on sustainable design through stakeholder involvement and consideration of the cultural and social aspects.

IV. DESCRIPTION OF EPICS@MINES

A. *Model EPICS Programs*

EPICS is an example of a National Science Foundation (NSF) supported innovation in engineering education that has been known to present engineering in context, prepare students for the profession, and impact their engineering identity [23], as well as significantly improve the diversity of those participating [24]. In EPICS, teams of undergraduates earn academic credit by partnering with local or global not-for-profit community organizations to define, design, build, test, and support engineering-centered projects to improve their ability to serve the community.

In contrast to typical engineering curricula, EPICS is multidisciplinary and vertically-integrated allowing students to interact with others from diverse education backgrounds. Furthermore, the curriculum structure allows students to participate for several semesters where they can take on different roles from project manager to partner liaison. Advisors, including both faculty and professionals, mentor the teams. This connection to a real-world project allows students to naturally develop professional skills through their work with each other, community partners, and advisors. Multidisciplinary teams working on projects for stakeholders addresses the needs for developing complex thinking skills and incorporating sustainability into engineering education.

Originally founded at Purdue University, EPICS has been recognized for its curricular innovation by the National Academy of Engineers with the Bernard M. Gordon Prize for Innovation in Engineering and Technology Education in 2004, as an NSF exemplar of programs "Infusing Real World Experiences into Engineering Education in 2012, by NSF's Corporate Foundation Alliance as an Exemplar Program in 2002, by the Chester Carlson Award for Innovation in Engineering in 1997 and 2012, and as a signature program by the Institute of Electronic and Electrical Engineers Foundation in 2013.

With its focus on engineering in context, EPICS has also been proven to be an effective method of encouraging women and under-represented groups in engineering. This has been shown to be particularly true in the EPICS@Purdue program. At Purdue, EPICS has grown to cohorts of over 400 students each semester, representing more than 70 majors. In the spring of 2014, 29.9% of the participants were female, while 46.7% of the participants were non-Caucasian. Additionally, 120 first-year students participate through the EPICS Learning Community, which was 54% female in the fall of 2014. Over a 20-semester period, female participation from Electrical and Computer Engineering in EPICS was on average 77% higher than the overall school enrollment [24]. Data have also shown that EPICS is meeting the goals of teaching professional and design skills, such as sustainability and cultural awareness, that are difficult to teach in traditional curriculum [23].

B. EPICS@Mines

The EPICS program at South Dakota School of Mines and Technology (SDSMT) was launched at the beginning of the fall 2016 semester and is closely aligned with the aforementioned successful model at Purdue. The unique aspect of EPICS@mines is the inclusion of Native American students as design collaborators for projects that benefit the Pine Ridge Reservation (PRR) in South Dakota. As such, including both Native American students at SDSMT and pre-engineering students at Oglala Lakota College (OLC) is an emphasis of the program. It is the first of EPICS consortium universities to collaborate with a tribal college.

As previously mentioned, diverse backgrounds and stakeholder involvement are necessary for sustainable design. For projects focused on meeting the engineering design needs of Native American communities, it is critical to work with tribal colleges and universities (TCUs), as they are both stakeholders and potential sources of innovation [26]. These collaborations also seek to increase Native American participation in STEM fields as there is a documented need to increase the numbers of Native Americans with STEM or related degrees. For example, a 2005 study by the US Department of Interior indicated that only 5.7% of the Native American population on PRR had a bachelor's degree. Incorporating social context in the learning process has previously been successful in engaging Native American students and addressing Native American community issues, leading to increased retention [26]. The EPICS program utilizes the same approach through its collaborative, community-based design projects to attract Native American students to STEM.

C. Past Collaborations as Foundation for Future Projects

The engineering students at SDSMT have learned how to integrate the various mechanical, electrical, civil, and computer engineering aspects of a problem throughout the years through multidisciplinary capstone design projects. While important, these design projects do not encompass the cultural differences that often exist between engineers and stakeholders, which is particularly important when the stakeholders are Native American. Through the existing multidisciplinary design process, the engineering students understand the integration of various technical components, but have difficulty understanding the social needs [23]. As such, a goal of EPICS@mines and the subsequent research is to integrate community members and stakeholders into the design process to aid student's abilities to incorporate social and cultural aspects into design. Ideally, this should improve student attitudes towards stakeholder participation with the idea of "working with" rather than "doing for" stakeholders. This emphasis on cultural understanding and stakeholder participation should also engage and retain both underrepresented students and those with diverse thinking styles.

In the development of student projects, EPICS has leveraged existing connections within the local community. The Principle Investigator on the project, Dr. Benning, was able to develop projects through her role as a committee member on the Rapid City Mayor's Committee on Sustainability, which is of particular interest for promoting sustainability through EPICS. Additionally, Benning, James Sanovia (an instructor at OLC, graduate student at SDSMT, and enrolled Lakota tribal member), and others have collaborated on projects on the PRR since 2011 through partnerships with tribal government agencies, such as the Oglala Sioux Tribe's Environmental Protection Program, and non-profits, including the Thunder Valley Community Development Corporation and the Native American Sustainable Housing Initiative.

To strengthen the existing collaboration with OLC, EPICS has continued to work with OLC and the Lakota community to establish engineering design projects that meet the needs of the PRR community with the goal that 50% of the EPICS projects will have this focus. It is the intention that these projects will serve as case studies for project based service learning (PBSL) collaborations, which were created under an on-going NSF engineering educational effort titled "Oglala Lakota College/South Dakota State University/South Dakota School of Mines and Technology Pre-Engineering Education Collaborative" (OSSPEEC). The OSSPEEC program is a collaborative effort between Tribal (OLC) and mainstream universities (SDSMT and SDSU) with a PBSL approach to enhance STEM teaching methods for Native American students.

The creation of the EPICS@mines program, partnered with OLC, allows the extension of this community-based PBSL. The projects developed through the EPICS program are directly transferable from the PBSL projects that were already underway in Tribal communities through the OSSPEEC program. Additionally, through EPICS, two OLC students per year receive summer stipends and SDSMT tuition. This provides continuity for long-term design projects and builds trust with community stakeholders, which is essential for long-term project success.

Through the NSF-OSSPEEC project, SDSMT established articulation agreements with OLC's Pre-Engineering Program that allows OLC students to take freshman to sophomore-level pre-engineering courses at OLC with a guarantee of credit transfer. As a part of EPICS, OLC pre-engineering students would have the additional opportunity to earn design course credits through collaborative, distance course offerings at SDSMT. This allows students the opportunity to earn credits and to establish personal partnerships, friendships, and mentorships at SDSMT that will encourage them in pursuit of their engineering degrees. These relationships have been identified as critical to student success [27, 28, 29]. Fig. 3 shows an example of a collaborative course between OLC pre-engineering students and SDSMT EPICS participants.

Additionally, from 2013-2015, Benning advised three multidisciplinary design teams, including mechanical, electrical, computer engineering students and interdisciplinary science students, that sought to design a system for sustainable food production on the PRR. The PRR is classified as a "food desert" by the US Department of Agriculture (USDA) meaning that the access to healthy, affordable food is limited [29]. This combined with low-

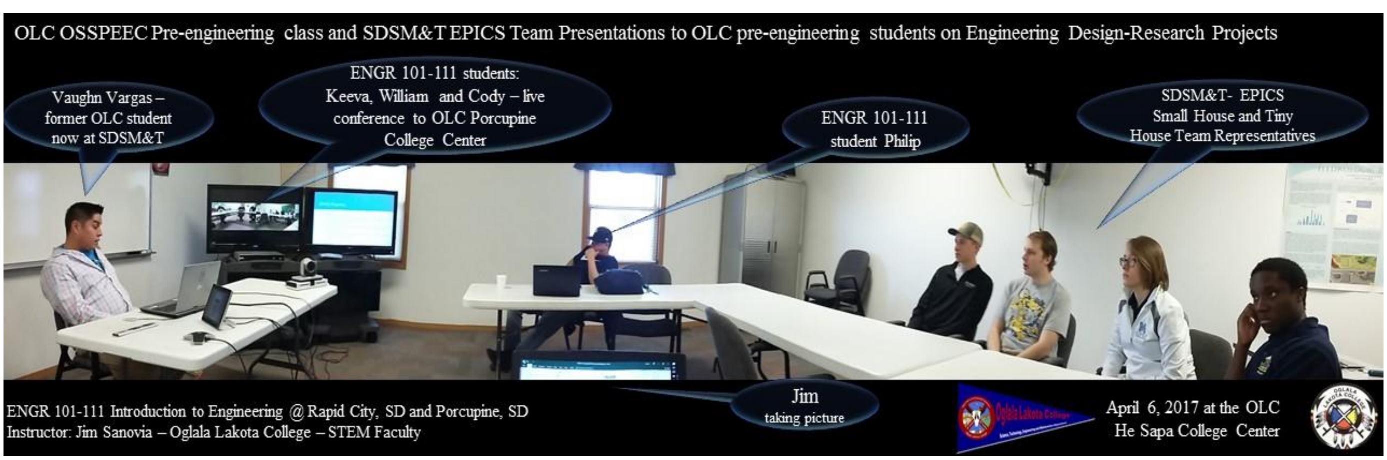

Fig. 3 Collaborative distance course about engineering design research projects including OLC pre-engineering students and SDSMT EPICS participants (Photo by James Sanovia)

income levels on PRR have created a complex issue. To combat the problem, local non-profits, such as the Thunder Valley Community Development Corporation have established food sovereignty initiatives. The design teams sought stakeholder participation from this organization among others throughout the design process in order to address the need for cultural awareness in engineering students while also delivering a sustainable, culturally-acceptable, affordable solution to the community. After the first year, Native American interns used the design report from the design team to finalize a design and construct a hoop house, selected as the final design based on performance, affordability, and stakeholder acceptance [26]. This then allowed the second design team to work towards enhancing the current design to meet the stated needs. The OSSPEEC program is considered a success for both the community and encouraging Native American students in STEM degrees. EPICS@mines adds a curricular component to these PBSL collaborations between OLC and SDSMT.

In the first year of EPICS@mines, five different project teams have formed. Three out of the five projects are working with PRR, the current projects are as follows:

- The iGrow team is working on a do-it-yourself seed starter kits with the mission to help develop agriculture and gardening practices on PRR
- OLC Food Sovereighnty Team is working to eliminate the food desert on PRR by continuing the aforementioned greenhouse project that started in 2014.
- OLC Housing Team is working to provide affordable homes that meet the needs of families on PRR
- RCAC Team is working to design a functional art cart to be placed in an art gallery that will encourage children to be involved in art.
- Tiny House Team is working to design and create tiny house solutions for the Western South Dakota Community Action Agency to combat the threat of homeless deaths in the winter in Rapid City, South Dakota.

V. RESEARCH

The overall goal is to engage culturally and intellectually diverse students, and improve student attitudes through the development and implementation of an EPICS program, with a dedicated portion of projects involving Native American students as design collaborators for projects that benefit the Pine Ridge Reservation in South Dakota. Research is being conducted to evaluate progress towards these goals. This paper only discusses the portion of the EPICS research goals related to promoting sustainability in engineering discussed throughout and are as follows: (1) evaluate the effectiveness of EPICS in engagement and retention of intellectually diverse students as measured through student typologies; (2) assess changes in student attitudes towards sustainability, stakeholder participation, and social awareness in engineering design. EPICS should provide an environment that values and promotes intellectual diversity by encouraging student engagement within a societal context. To measure this, intellectual diversity is being evaluated using the HBDI. Baseline data and the typological data will be tracked over time to determine the impact service learning has on retaining intellectually diverse students.

Additionally, participation in EPICS should improve student attitudes towards sustainability, social awareness, and stakeholder involvement in engineering. It is expected that students initially interested in EPICS may already have attitudes that support engineering as a means to benefit mankind meaning that it will be important to both understand student's initial attitudes and those developed in EPICS. These changes are currently being measured through focus groups. Overall, this research should provide added information about the impact of service learning on intellectual development and student attitudes.

IV. PRELIMINARY RESULTS

While EPICS@mines has only completed its first two semesters, simple demographics of its participants support previous claims of increased participation from females and underrepresented populations that were shown at Purdue.

In the first semester, EPICS students were:

- 41% female compared to 22% university-wide
- 14% Native American or other minority compared to 12% campus wide
- Total of 55% underrepresented

In the second semester, EPICS students were (Fig. 4):

- 43% female
- 7% Native American, compared to 2.1% university-wide
- 15% other minority
- Total of 65% underrepresented

In addition, the funded student mentors, interns, and research assistants were:

- 50% female
- 50% Native American

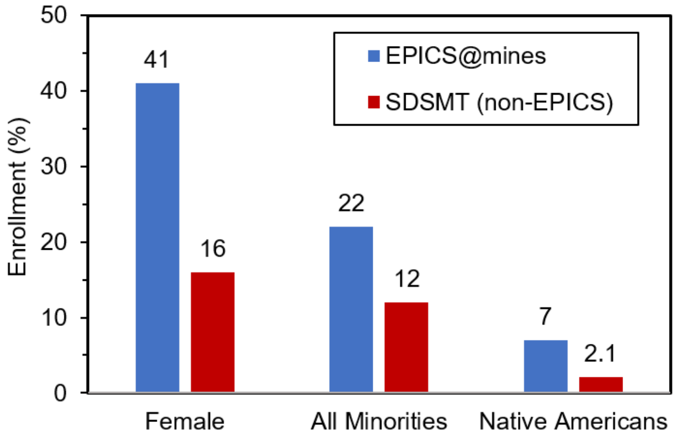

Fig. 4 EPICS@mines participants demographics in the second semester compared to SDSMT student population demographics.

Two focus group sessions were also conducted at the end of the second semester with IRB approval. A total of 11 students participated in the focus group sessions. Students were asked a series of questions related to stakeholder involvement in the design process, the influence of sustainable design, and the perception shifts regarding ethnic and cultural decisions in the design process. Students were universal in their support of stakeholder involvement. While most disciplines teach stakeholder involvement, it is not a universal construct in the design experience. Most students recognized that such involvement not only influenced design considerations but also recognized a greater need for working within the cultural and societal context in which a design is to be incorporated. Students also developed a greater appreciation for sustainable design considerations although this was found to be dependent on the project. For example, the iGrow and Tiny House teams specifically mentioned sustainable design considerations in their projects that would not likely have been realized outside of EPICS. The focus group also revealed strong interest in continued participation in EPICS. Specifically, 7 of the 11 students participating in the focus group sessions will be returning to SDSMT next fall and all 7 planned to continue in EPICS.

These preliminary results are encouraging in showing that focusing on sustainability and service learning in engineering education can improve students' perspectives on sustainable design and enhance the diversity the of engineering student population and ultimately the engineering workforce.

V. Conclusion

Future engineers must be able to incorporate sustainability into all aspects of their designs to meet the increasing demands of complex real world problems. Consequently, engineering educators have been challenged to integrate sustainability into existing curricula. Sustainability is a particularly complex problem that requires diversity to foster innovation. Service learning programs have been shown to be an attractive and effective method to blend sustainability into engineering education curricula while also encouraging diversity in engineering. In particular, Engineering Projects in Community Service (EPICS) is a well-established service learning program at 24 universities that has been known to accomplish this by presenting engineering in context and preparing students for the profession. An EPICS program has been established at South Dakota School of Mines and Technology with a special emphasis on collaborating with Native with special emphasis on collaboration with Native American students. Research is being conducted to measure the program's effectiveness, particularly evaluating EPICS ability to attract and retain an intellectually diverse student population, and the impact EPICS has on students' attitudes towards sustainability, social awareness, and stakeholder involvement in engineering.

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References

[1] National Academy of Engineers, 2004, The Engineer of 2020: Visions of Engineering in the New Century. The National Academies Press.

[2] Phase II. Educating the engineer of 2020: Adapting engineering education to the new century. National Academies Press; 2005 Nov 6.

[3] Civil Engineering Body of Knowledge for the 21st Century.(2008).

[4] ABET (Accreditation Board for Engineering and Technology). (2015). "Accreditation criteria and supporting docs." ⟨http://www.abet.org/accreditation/accreditation-criteria/⟩

[5] Benning, J., and Shearer, C., "Example of a Vertically Integrated Sustainable Engineering Program." *Journal of Professional Issues in Engineering Education and Practice*, April 2016.

[6] Segalas, J., Ferrer-Balas, D. and Mulder, K.F., 2010. What do engineering students learn in sustainability courses? The effect of the pedagogical approach. *Journal of Cleaner Production*, *18*(3), pp.275-284.

[7] Coyle, E. J., Jamison, L. H., & Sommer, L. S. (1997). EPICS: A model for integrating service-learning into the engineering curriculum. *Michigan Journal of Community Service Learning, 4*, 81-89.

[8] Edmund Tsang, E. (2007). Projects that Matter: Concepts and models for service-learning in engineering. Sterling, VA: Stylus.

[9] Hugg, R., & Wurdinger, S. (2007). A practical and progressive pedagogy for project based service learning. International Journal of Teaching and Learning in Higher Education, 19(2), 191-204.

[10] Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2013). The ABET "Professional Skills" - Can theybe taught? Can they be assessed? *Journal of Engineering Education, 94*(1), 41-55.

[11] Greene, J. C. (1987). Stakeholder participation in evaluation design: Is it worth the effort? *Evaluation and Program Planning, 10*(4), 379-394.

[12] Guest, J. S., S.J. Skerlos, J.L. Barnard, B. Beck, G.T. Daigger, H. Hilger, S.J. Jackson, K. Karvazy, L. Kelly, L. Macpherson, J.R. Mihelcic, Am. Pramanik, L. Raskin, M.C.M. Van Loosdrecht, D. Yeh, N.G. Love. (2009). A new planning and design paradigm to achieve sustainable resource recovery from wastewater. Environmental Science and Technology, 43(16), 6126-6130.

[13] Fischer, G., & Shipman, F. (2013). Collaborative Design Rationale and Social Creativity in Cultures of Participation. In J. M. Carroll (Ed.), *Creativity and Rationale* (Vol. 20, pp. 423-447): Springer London.

[14] Zimmerman, J. B., & Vanegas, J. (2007). Using Sustainability Education to Enable the Increase of Diversity in Science, Engineering and Technology-Related Disciplines. *International Journal of Engineering Education, 23*(2), 242-253.

[15] EPA's Report on the Environment: Sustainability, EPA. https://cfpub.epa.gov/roe/chapter/sustain/index.cfm

[16] Little, J., Hester, E., and Carey, C., 2016. Assessing and Enhancing Environmental Sustainability: A Conceptual Review. *Environmental Science & Technology,* pp 6830-6845

[17] Felder, R.M. and Brent, R., 2005. Understanding student differences. *Journal of engineering education*, *94*(1), pp.57-72.

[18] Kellogg, S., 2014, October. Building diversity by embracing intellectual diversity. In *Frontiers in Education Conference (FIE), 2014 IEEE* (pp. 1-4). IEEE.

[19] Karlin, J. and Kellogg, S. (2009). Metrics and the Holistic Learner, Research in Engineering Education Symposium (REES), Cairns, Australia.

[20] Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1998). Engineering student attitudes assessment. Journal of Engineering Education, 87(2), 133-141.

[21] Surovek, A.E. and Karlin, J. N. (2004), "Global and Societal Impact of Civil Engineering: Connecting Rural Students with the World," International Symposium on Engineering Education, Fribourg, Switzerland, Sept.

[22] Surovek, A.E. and Karlin, J.N. (2006), "Beyond the Classroom: Using a Lecture Series Format to Give Engineering Students a Societal and Global Context," Proceedings of the 2006 American Society for Engineering Education Annual Conference and Exposition, Chicago, IL, June.

[23] Benning, J., Surovek, A., Dolan, D., Wilson, L., Thompson, A. and Pyatt, R., 2014, October. Cultural considerations in service learning with American Indian Reservation community stakeholders. In *Frontiers in Education Conference (FIE), 2014 IEEE* (pp. 1-4). IEEE.

[24] Zoltowski, C.B. and Oakes, W.C., 2014. Learning by Doing: Reflections of the EPICS Program. International Journal for Service Learning in Engineering, 9.

[25] Matusovich, H.M., Oakes, W. and Zoltowski, C.B., 2013. Why women choose service-learning: Seeking and finding engineering-related experiences. *International Journal of Engineering Education*, *29*(2), pp.388-402.

[26] Pyatt, R., Benning, J., Tilsen, N., and Tinant, C. J. (2015). "Pedagogy into practice: Teaching environmental design through the native American sustainable housing initiative." Putting the local in global education, N. W. Sobania, ed., Stylus Publishing, Sterling, VA.

[27] Sawyer, J., Kant,, J., Benning, J., Fick, D., Burckhard,, S., 2014, Forging partnerships, experiential learning, and community impact: Capacity building matters, Proceedings of the ASEE Midwest Regional Conference, Iowa City, October 17, 2014.

[28] Kant, J. Burckhard, S., Kilts, Wl, Min, K (2014). Increasing diversity in engineering: Capacity building matters, Proceedings of the ASEE Midwest Regional Conference, Iowa City, October 17, 2014.

[29] Tinant, Cl, Kant, J., LaGarry, H., Sanovia, J., Burckhard, S. (2014). Building trust, experiential learning, and the importance of sovereignty: Capacity building in pre-engineering education - A tribal college perspective, Proceedings of the ASEE Midwest Regional Conference, Iowa City, October 17, 2014. Smith, K.A., Sheppard, S.D., Johnson, D. W., and Johnson, R.T. (2005) "Pedagogies of Engagement: Classroom- Based Practices," Journal of Engineering Education, 04(1), pp. 87-102.

[30] US Department of Agriculture, Agriculture Marketing Services. FoodDeserts. http://apps.ams.usda.gov/fooddeserts/foodDeserts.aspx