



## **Research Initiation: Effectively Integrating Sustainability within an Engineering Program: Project Accomplishments**

### **Dr. Paul Gannon, Montana Engineering Education Research Center**

Associate Professor, Chemical Engineering Associate Director, Montana Engineering Education Research Center

### **Dr. Carolyn Plumb, Montana State University**

Carolyn Plumb is the recently retired Director of Educational Innovation and Strategic Projects in the College of Engineering at Montana State University (MSU). Plumb has been involved in engineering education and program evaluation for over 25 years, and she continues to work on externally funded projects relating to engineering education.

### **Dr. Ryan Anderson, Montana Engineering Education Research Center**

Dr. Anderson received a BS in Chemical Engineering and a BA in History from Bucknell University in 2007. He obtained a PhD in Chemical and Biological Engineering at the University of British Columbia in 2012 before postdoctoral studies at City College of New York. He is currently an assistant professor at Montana State University.

# **Research Initiation: Effectively Integrating Sustainability within an Engineering Program – Project Update**

## **Abstract**

The overall research aim of this NSF Research Initiation in Engineering Formation project was to improve the professional formation of engineers by integrating sustainability within engineering education programs. The objectives included initiating research into: the attitudes of engineering faculty and students toward sustainability; the effectiveness of integration approaches within undergraduate engineering courses; and, engineering-identity formation processes in 4<sup>th</sup> grade students. A previously-reported faculty survey indicated general support for integrating sustainability into engineering education, and a desire for associated professional development opportunities. Survey results helped motivate the creation of an engineering education research center, and a workshop series on education research methods facilitated in-part by internationally-recognized experts. The Engineering Professional Responsibility Assessment was administered to two consecutive cohorts of engineering seniors and results indicated students are significantly motivated by the perception that the engineering profession helps society, and they identified specific courses and experiences within and outside of the engineering program which influenced this motivation. The PIs also developed, implemented and reported on an engaging engineering course module to integrate sustainability, which students described as enjoyable, challenging and effective in their learning on a contemporary and contentious engineering application; fracking. Finally, the Draw an Engineer Test was administered to local 4<sup>th</sup> grade students, and results inspired the exploration of the Identity-Based Motivation framework to inform future educational interventions aimed at diversifying engineering-identity formation processes.

## **Engineering Education Research (EER) Capacity Building**

An intra-institutional engineering faculty survey (administered in 2016) showed general support for EER as well as favorable attitudes towards sustainability and its integration into engineering education, and a desire for associated professional development opportunities to facilitate both. Survey results helped motivate the creation of an EER center, a workshop series and certificate program on EER methods, and a workshop series focused on integrating sustainability into engineering education. The workshops are facilitated by internationally-recognized EER and sustainability experts, and engineering faculty attendees have ranked them as very effective in helping frame their EER efforts. Since the EER center's inception, which was catalyzed by this project, the number of engineering faculty members engaged in the EER center activities, along with the amount of externally-funded EER projects and both institutional and foundational (alumni) support has increased multi-fold. This project has thus contributed significantly to the initiation and growth of EER capacity at a welcoming institution.

## **Engineering Students' Professional Responsibility Assessment**

The Engineering Professional Responsibility Assessment (EPRA) [1] was developed to measure students attitudes and dispositions towards the social responsibility dimension of sustainability. The EPRA was administered to two consecutive cohorts of engineering seniors (Spring 2016 &

2017) and results indicated that most (>50%) students are significantly motivated by the perception that the engineering profession helps society, and this led to their choice of major. Students also identified specific courses and curricular and extracurricular experiences within and outside of the engineering program which influenced this motivation. Interpretations of survey data are being leveraged for continued research efforts and are significantly informing recruitment, retention and curriculum development efforts.

### **Developing Sustainability Interventions for Engineering Courses**

The project team developed, implemented and reported on an engaging engineering course module to integrate sustainability, which students described as enjoyable, challenging and effective in their learning on a contemporary and contentious engineering application; fracking. The reported study, to be published in an EER journal, describes an adaptable and transferable classroom activity that combines active learning and teamwork to critically evaluate sustainability topics in contemporary engineering contexts. The study, summarized below, included activities within a core engineering course, fluid mechanics, and two elective courses on sustainable energy – one designed for upper-level engineering majors, and the other for entry-level non-engineering majors.

Preceding the activity day, students received formal instruction from a university librarian or course instructor regarding online research methods, sources and their biases, and were encouraged to bring a portable electronic device to the next class (personal or library-loaned). The activity consisted of five randomly-assigned student groups with a specific focus of fracking in the context of: (1) science/technology; (2) economics; (3) policy; (4) society; and, (5) the environment. Each class then watched two short (about 5 minutes) info-videos on fracking (one produced by industry and another by a science literacy advocacy group). Groups researched their specific foci online during class, discussed and summarized their findings within each group, and subsequently shared via instructor-facilitated class discussions.

Pre- and post-activity assessments included collecting both quantitative and qualitative data to evaluate student understanding, perspectives and opinions on fracking, the information sources they used before and during the activity on fracking, as well as the activity itself. Ten pre/post-activity statements were presented to students with a 5-point scale, which was converted to corresponding 5-1 numeric values (5 = strongly agree) for quantitative analysis. Three post-activity open-ended questions were used to qualitatively aide in interpreting the quantitative data.

Quantitative pre- and post-activity assessments demonstrated the efficacy of the approach on effective student learning, and qualitative assessments based on student responses to open-ended questions indicate student engagement and preference over a lecture-based approach. Course assignments and exam questions were developed to integrate the sustainability impacts of basic engineering design, e.g., pump sizing for fracking operation, as well as assess legacy impacts of the class activity.

## **Engineering Identity Formation in Elementary Education**

The Draw an Engineer Test (DaET) [2] was developed to assess attitudes of young students, e.g., 3-5<sup>th</sup> grade, toward the engineering profession and has been used to assess engineering identity formation processes at this critical age. In this project, the DaET was administered to 4<sup>th</sup> grade students at a local (suburban) elementary school and at a regional (rural) Native American reservation. The DaET results and their diversity inspired the exploration of the Identity-Based Motivation (IBM) [3] framework to inform future educational interventions aimed at diversifying engineering-identity formation processes. A recently-submitted proposal by the PI describes the design and development of IBM-informed digital game-based learning interventions to foster individualized engineering identity formation in diverse students.

### **Overall Assessment**

Several independent research thrusts began via the single topic of sustainability. From 4<sup>th</sup> grade students, to university students, to faculty, sustainability topics were leveraged for the goal of better preparing, recruiting and retaining engineers. By assessing diverse cohorts of 4<sup>th</sup> grade students (suburban, rural/reservation), IBM interventions will be further pursued as a research endeavor to help attract more students into engineering earlier in their educational experiences. The fracking activity reached several hundred students via three courses: two elective courses on sustainable energy (one designed for entry-level non-STEM students); and, a core engineering course on fluid dynamics. The sustainability topic presented in an engineering context can help recruit non-STEM students into engineering from the entry-level course. By approaching the fracking topic from a variety of angles to engineers in the technical courses, these engineers are better prepared to face large, complex problems. And by engaging the faculty at the University, these efforts can have a larger impact beyond the three courses taught by the investigators. Surveyed faculty indicated support for sustainability modules for their classes but acknowledged a lack of resources and training to move forward. The EER formed in part by this work is actively addressing that gap. Thus, the RIEF project successfully initiated several unique projects within this overarching sustainability framework.

### **References**

- [1] N. E. Canney and A. R. Bielefeldt, "Validity and Reliability Evidence of the Engineering Professional Responsibility Assessment Tool," *Journal of Engineering Education*, vol. 105, no. 3, pp. 452-477, 2016.
- [2] C. C. Meredith Knight, "Draw an Engineer Test (DAET): Development of a Tool to Investigate Students' Ideas about Engineers and Engineering," in *American Society for Engineering Education Annual Conference & Exposition*, Salt Lake City, 2004: ASEE.
- [3] D. Oyserman and M. Destin, "Identity-Based Motivation: Implications for Intervention," *The Counseling Psychologist*, vol. 38, no. 7, pp. 1001-1043, 2010.