Graduate Student paper

Multidisciplinary and Dual University Undergraduate Research Opportunities: A Low Stakes/High Impact Practice that Engages Underrepresented Populations in Engineering

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Abstract

Engineering students are inundated with high-stakes scenarios like exams and projects saturated with expectations of excellence. Students rarely are granted an opportunity to escape these expectations and design, develop, and build a project lead predominately by their peers. We have taken an opportunity to challenge these traditional expectations and offer a multidisciplinary research experience spanning two universities addressing survivability during extreme weather. The group of students on this project span multiple critical identities, many of which underrepresented in engineering. This work will qualitatively examine the experiences of those students and how it has impacted their time as undergraduate engineering students.

Introduction

Undergraduate engineering students are some of the busiest students on a college campus with homework, labs, professional organizations, and social organizations all demanding a significant portion of their time. Traditional extracurricular or co-curricular undergraduate activities related to research place added effort and time burdens on students beyond their already busy schedules, and often those activities expect significant involvement from those students throughout a semester or academic year. We understand that the time students have is precious and plays a critical role in shaping their experiences as growing adults along with their performance (Burke et al., 2017; Liao et al., 2013). Considering the strain on time for these students was a priority when developing an interdisciplinary engineering undergraduate research experience. This work examines the experiences of undergraduate students working in an interdisciplinary team from two Texas Land Grant Universities on a research project to tackle a social and technical problem for the residents of the state of Texas. Interviews were conducted with three students to understand the impact of this experience on their personal and academic lives. This extracurricular undergraduate research experience was provided for undergraduate engineering students at two significantly different

universities from a variety of disciplines and backgrounds.

Background

The undergraduate research project this work is examining centered around the problem of survivability during extreme weather conditions in the state of Texas. The freeze in February 2021 resulted in the loss of life and power across Texas when 50% of the natural gas power plants failed due to a lack of preparation for extreme cold (Ghosh et al., 2021). These natural gas power plants provide more than half of the electrical power in Texas, resulting in a drastic drop in power distribution when they were rendered inoperable during this storm. This type of failure is not unheard of in the state of Texas with 2011 and 2014 also being significant years in which the power grid in Texas has been subject to failures related to extreme cold temperatures (Ghosh et al., 2021). The Electric Reliability Council of Texas (ERCOT) urged power providers to implement weatherization measures to ensure this would not occur again in 2011, however, in 2014 Texas was again at the brink of power failure when equipment related to these natural gas powerplants froze (Ghosh et al., 2021). Unfortunately, the efforts to weatherize these natural gas plants proved to fail during the freeze in 2021. Understanding the need for change faculty at Texas A&M University applied for internal funding to support a team of undergraduate students to find innovative solutions to this issue at a variety of levels.

The undergraduate team that was assembled was of multiple academic, ethnic, and socioeconomic backgrounds at two Texas Land Grant Universities both with minority serving institution status. This team was formed organically through word of mouth and promotion by the faculty who were awarded funding and faculty interested in support the efforts of this research. The students of this team presented a conference paper at a regional conference in 2022 and a poster at the ASEE Annual 2022 conference as products of their work (Mills et al., 2022). This project has officially ended; however, some members of this team have continued with this work of their own volition with support from a graduate student mentor and faculty mentors associated with this work.

This project began in the Fall of 2021 and extended to the Summer of 2022. Weekly zoom meetings were conducted to for leadership to check in with the undergraduate students. Several in-person meetings were arranged over the Fall 2021 and Spring 2022 semesters for these students to meet and work together. The first of these was a day in which Raspberry Pi and Arduino microcontrollers and sensors were given to those students to tinker and experiment with to spark ideas for problem solving. Several teams were formed to address various components of the research throughout the tenure of the project and students were provided the opportunity to shift between teams as their efforts and expertise were needed. Financial compensation was also offered to students who requested to be compensated and were eligible as student workers, regardless of the institution they were attending to ensure that the time spent on this project would not interfere with the earning potential of students attempting to balance their academic and extracurricular activities with gainful employment necessary for survival.

The final goal decided upon by the team was to develop a survivability kit and survival guidebook. The survivability kit was developed to be affordable, easy to implement in a variety of dwellings,

and scalable for a variety of potential users. Various sensors were assembled to monitor conditions within the home to control the climate of a comfortable living space, proper air quality, suitable drinking water quality, and proper non-perishable food storage. The guidebook was developed to explain how to use the materials provided in the kit as well as troubleshoot and maintaining the kit's various sensors and systems. The guidebook also provides suggestions for added comfort of a user such as battery power storage, expandable water storage, and more flexible food preparation.

The development of these components for the project were challenging for the team and stretched them beyond their individual disciplinary scopes they would normally be focused on in their engineering programs but provided a real world scenario of both engineering collaboration and problem solving that could potentially impact communities in the state of Texas.

Literature

Work by Liao et al. (2013) frames the modern university as a complex social organization in which students must budget their time amongst the various components of just such a social organization. Liao et al. (2013) comments on the encroachment of corporate time into public time that happens in higher education while universities trend towards an increasingly corporate framework of operation where time is valued as money. Time management for engineering students is particularly complex. Tyson (2012) examined negative impacts on student employment on their time management and retention as well as time to degree through a set of interviews with faculty, administration, staff, and students. This work by Tyson (2012) shares narratives from those populations mentioned and constructs the understanding that this is a complex problem for students and the understanding from non-students varies in acceptance of their individual needs requiring employment. However, the conclusion of Tyson (2012) stating that faculty, administrators, and staff believing students will understand the benefits of engineering degrees being worth the sacrifice of student employment is shortsighted and largely disregards the need for many students, particularly underrepresented groups in engineering who are struggling financially to even pursue a degree in the first place.

The theory of student departure by Tinto (1993) frames an understanding of the reasons student attrition may occur and he suggests that increased involvement at university has the potential for increased retention among students. One of the main reasons cited by Tyson (2012) for students to pursue gainful employment outside of the university's circle of influence is simply survival, especially of students depending on themselves to afford higher education costs. Maslow and Lewis (1987)'s hierarchy of needs clearly places those physiological needs that are only achievable through basic financial stability as the bedrock of a person's needs.

Extracurricular Design-Based Learning is a combination of project-based and design-based learning that situates itself in a service focused environment. It is a model that presents students with opportunities to design solutions to everyday challenges to be better prepared to enter the workforce. In many engineering institutions, students ask for more "real-world" experiences in order to truly practice the theory they learn inside the classroom in practical and real scenarios (Gerber et al., 2012)

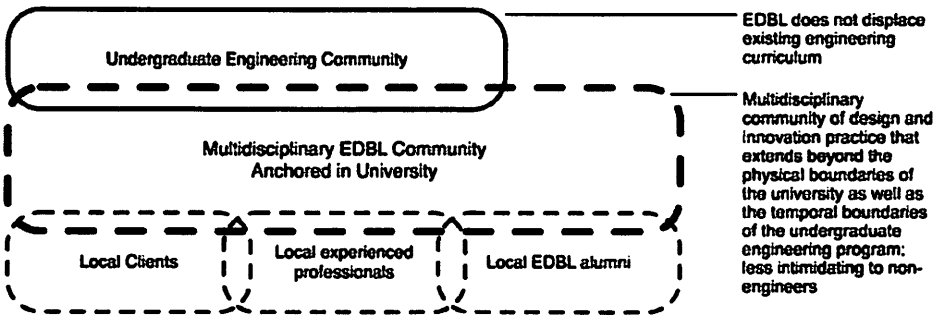

Figure 1: Engineering Design-Based Learning Concept Map (Gerber et al., 2012)

Methods

Three semi-structured interviews were conducted with students who were apart of the undergraduate research team. Each participant will be referred to by a pseudonym beginning with the first three letters of the alphabet to easily categorize the participants. Albert is a Latinx man studying Architectural Engineering at Texas A&M University, Bernice is a White woman studying Architectural Engineering at Texas A&M University, and Calvin is a Black man studying Electrical Engineering at Prairie View A&M University. These three students were interviewed by a researcher who they were not acquainted with, limiting potential conflicts of interest between the participants and the researchers. The interview questions are as follows:

1. How would you describe your experience working on the Innovation [X] project this past year?
2. In what ways have your experiences in the Innovation [X] undergraduate research project influenced your experience as an undergraduate engineering student at Texas A&M University?
3. Can you describe how participating in the Innovation [X] project has made you feel regarding feelings of belonging or inclusion?
4. How have your own personal identities (I.E. Man, Woman, First-Gen, Latinx, etc) impacted the ways in which you have participated in the Innovation [X] project?
5. How have you been or felt supported by the leadership of the Innovation [X] project over the last year?
6. How would you describe your experience with having been mentored in the Innovation [X] project by the graduate student working with you?
7. What about the Innovation [X] project has been particularly impactful for you personally?
8. What would you have liked to see or would like to see in future Innovation [X] projects to better support you as an undergraduate engineering student and undergraduate researcher?

These interviews were conducted using the video conferencing platform Zoom where the audio of the session was recorded, and the automatic transcription associated with Zoom was used to transcribe the content of the interview. Those transcripts were checked for accuracy and analyzed

using NVIVO, a qualitative analysis software (Phillips & Lu, 2018). An inductive emergent open coding methodology was used to codify the content of these interviews and overarching themes were derived from those transcripts (Holton, 2007).

Results

From these interviews overarching themes were identified related to these student's experiences participating in the undergraduate research project operated by the authors. The overarching themes are as follows: *career development, inclusion, meaningful networking, mentorship, positive experiences, and real engineering experiences.* Of the students interviewed all considered participating in the research experience to be positive for their careers in engineering although what was most positive for each participant varied.

Albert found that having a shared identity with a mentor to be significant to his experience. This shared identity paired with the relationship he built with this mentor provided him an opportunity to reframe how he views his own future in engineering and provided him with a model of how someone with a similar background can choose to pursue education beyond that of a bachelor's degree.

Bernice found that the flexibility of the program allowed for her participation to continue to be meaningful throughout the duration of the project even when she was inundated with coursework, eventually jumping back into the project when her schedule allowed.

Calvin found that coming from Prairie View A&M University and working on the project with students from Texas A&M University was an enriching experience and allowed him to better understand his strengths and weaknesses when working with an interdisciplinary team.

All participants remarked on how welcoming and supportive the leadership of the project was making them feel a sense of professional respect they had not experienced yet. Learning vital skills on the job was also considered by the participants to be essential to cohesively solving the problems set out in front of them while not being made to feel unprepared by lacking that knowledge before joining the project.

All participants mentioned how the flexibility of the program was conducive to their success both in the project and in their courses by not having to choose to sacrifice one over the other but to instead participate in the project when their busy lives allowed.

All participants remarked on a feeling of belonging when participating in the project while Bernice contrasted that sense of belonging with her experiences feeling othered by her peers in her first-year engineering coursework at Texas A&M University. Calvin coming from Prairie View A&M University felt at first uncertain that he would be able to contribute at the same level students were participating at Texas A&M University due to the funding university being Texas A&M University, however after participating in the remote collaborative setting found that he was equally as prepared and, in many ways, more prepared to participate in such a research project.

Summary and Conclusions

Engineering students are embarking upon some of the most challenging and stressful years of their early adulthood when they walk onto their respective college campuses. It is clear from work by Tyson (2012) that many faculty, staff, and administrators simply do not understand the struggles that engineering students are facing financially, and believe that students are working for the sake of financial gain, however the reality is that students have to manage their time amongst a multitude of necessary commitments simply to survive while being students. Extracurricular Design-Based Learning (Gerber et al., 2012) is a proven way to engage students and aligns with Tinto (1993)'s theory of student departure by engaging students to bring them closer to graduation. The project developed and operated by the authors of this work intentionally designed a flexible commitment system into the project participation to be mindful of the struggles members would face as engineering students. The decision to offset any lost wages by participating in a monetarily compensated capacity resulted in a committed core group of students over a full academic year. Among those students interviewed for this work (Albert, Bernice, and Calvin) all have experienced positive results from participation and have taken different things away from this experience that will hopefully follow them into their careers. Flexible Engineering Design-Based Learning and multi-university collaborative research in the context of this work has resulted in a highly impactful experience for engaging students and future work following similar collaborative design hopes to prove this type of undergraduate engineering extracurricular research activity as an effective option for modern engineering students balancing the time available in their lives.

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