THE CHEM-E-CAR AS A VEHICLE FOR SERVICE LEARNING

Through K-12 Outreach

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If you have a highly active student chapter, you have probably heard of the Chem-E-Car competition, which is hosted by the American Institute of Chemical Engineers (AIChE). In this competition, students design and build a car that runs on a chemical reaction following strict adherence to safety protocols. At the time of the competition, a weight of water to be carried and a distance to be travelled by the car are announced, and runs are scored primarily by how close the car stops to the target distance. The focus on safety is such that student teams must perform a job safety analysis and prove that their car is safe to be qualified to run, and teams are not necessarily qualified just by adhering to the safety regulations outlined in the competition rules.

This program utilizes the established principle that outreach efforts can be made highly effective by utilizing undergraduate students to engage K-12 students through hands-on demonstrations.[1] It is known that early and continued exposure to science and engineering are keys to getting and keeping students interested in these subjects through their higher education and into their careers.[2] Furthermore, outreach activities have been found to help with retention rates of underrepresented groups in engineering.[3]

One of the major benefits for the undergraduate students and the engineering profession is the emphasis on safety. The program at Oklahoma State University has developed a partnership with industry to provide professional guidance with their safety review.[4] This more intensive level of safety analysis also results in a more thorough review and a safer process and vehicle.

As with most endeavors, a Chem-E-Car team cannot succeed without some investment of time and money. While the amount of faculty time and departmental funding required to sustain a Chem-E-Car team are fairly modest, it can be a difficult commitment to make when both quantities are limited. Therefore, the benefits of initiating or supporting such a team should be briefly mentioned first to emphasize that this is a wise investment of these valuable departmental resources. An active AIChE chapter and Chem-E-Car team serve as excellent visual benchmarks that illustrate a department's dedication to the undergraduate experience and educational mission. These groups can indirectly aid in recruiting the next generation of engineering students by enhancing the undergraduate experience, and these activities may be used in the departmental advertisements and may be reported by the local news media. Especially after some promotion, these activities can be used to solicit donations from industry to support a chapter, so that instead of being a "sink" for funds, these activities can be ultimately leveraged to be used as a fundraising activity for a chapter so that it may be self-sustaining with contributions from local industries. In summation, a robust Chem-E-Car team with a service-learning mission can strengthen relationships between students, faculty, industry, and the department which benefits all parties involved.

Beyond outlining the benefits of fostering a "typical" Chem-E-Car team in your department, this article describes the success of University of Louisiana (UL) at Lafayette's

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local chapter with using the Chem-E-Car team to perform outreach to local K-12 students through a service-learning course. While this combined Chem-E-Car and outreach program started with the author conducting a service-learning project funded by a ULS (University of Louisiana System) Serves grant in 2009, the program has continued with the ongoing support of local industries that have been impressed by the accomplishments of the participating students. The level of success of this program has exceeded the author's expectations due to the synergy that was discovered when undergraduate education, volunteerism, and competition come together in a service-learning model.

SERVICE-LEARNING SYNERGY THROUGH K-12 OUTREACH

Oftentimes, students have the mindset that they need to be well-established in their career before they can begin to give back to their local or professional community. Yet, even in their first or second year, they can begin to give back to their community by encouraging K-12 students to pursue engineering or other STEM disciplines. Many K-12 students do not have a good understanding about what engineering entails and how a four-year engineering degree can be the start of a challenging, yet rewarding, career. By reaching out to K-12 students, we can motivate them to pursue degrees in STEM disciplines. Motivated high school students can then take steps to prepare for college by devoting more time and energy to studying math and science. College students often serve as role models for high school students, and have the potential to relate and communicate to high school students better than teachers and professors. This is especially true when these students return to their former high schools and communities through outreach activities.

Outreach programs help build the self-esteem of the undergraduate participants who now serve as mentors instead of students. The participants build technical, persuasive presentation skills that are often underemphasized in engineering programs, even though interpersonal and communication skills are critical to both getting a job and succeeding in one's career. The Chem-E-Car design and competition serve to demonstrate what engineers can do, and as such, it serves as a very tactile visualization of engineering for these outreach activities. The undergraduates then have the opportunity to present their work, of which they are rightfully proud. Students in our program can have their work recognized with independent study credit if they can document enough hours dedicated to the building of the car and K-12 outreach. An impressive synergistic relationship was discovered when the drive of the Chem-E-Car team was combined with service-learning through outreach programs. The increased prestige of the local chapter resulting from the Chem-E-Car team's competition and outreach helped to solicit funds for the continuation of these activities in an auto-catalytic cycle.

DESCRIPTION OF SERVICE-LEARNING COURSE

At first, it may seem difficult to justify awarding course credit for participating in the Chem-E-Car competition and volunteering for outreach. However, after looking more closely at the activities involved, we found that this one-credit service-learning course provided more professional training and covered more ABET objectives than most three-credit engineering lecture courses. Students develop technical skills by designing the car, conducting experiments, and modeling reactions and the system performance. As seen in Figure 1, students on the team often need to learn specialized skills then cooperate on a multidisciplinary team to put a car together, which should also instill an appreciation of the need for lifelong learning to adapt to new challenges. For instance, one

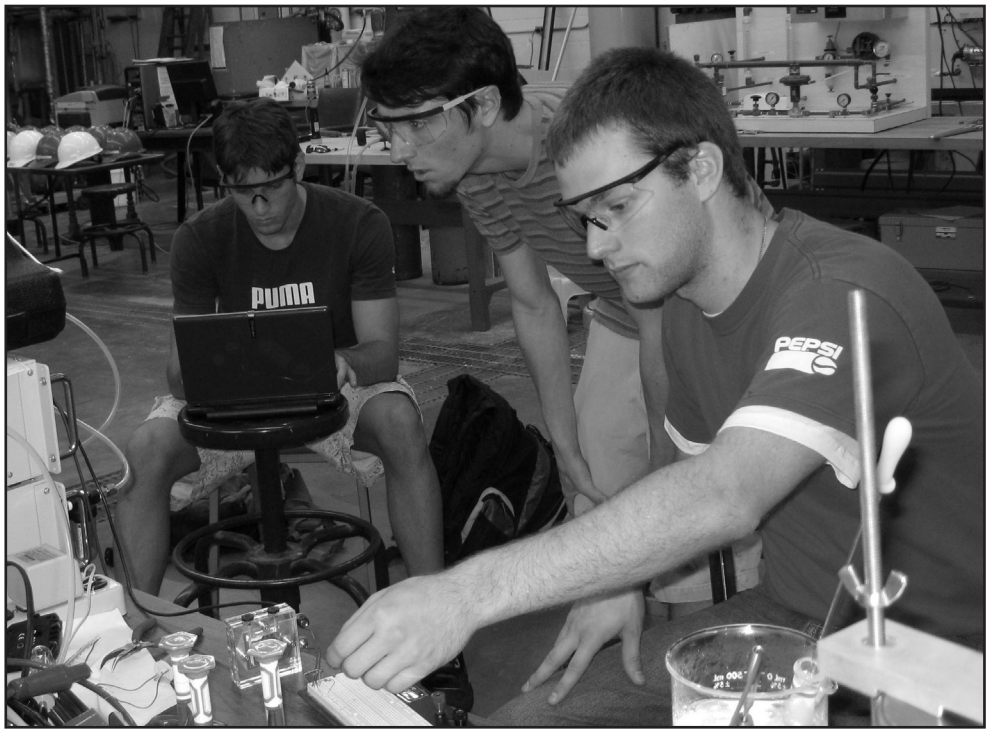

Figure 1. *Chem-E-Car team testing the electrical performance of their fuel cell.*

student may specialize in the electrochemistry and battery assembly, one may specialize in the mechanics of the drive system, and another may need to master the circuitry required to run a battery-powered car. Participation in the Chem-E-Car competition also develops interpersonal skills in teamwork, leadership, and conflict resolution.[5] Students in the course are also required to make oral presentations to local K-12 students, which strengthens their communication skills. The typical enrollment for this course ranges between three to eight undergraduate students from semester to semester including students in their sophomore, junior, and senior years. Freshmen are not barred from inclusion, but students typically do not learn about the program in time to register for freshman year. This course has been successfully implemented every semester as an elective independent study course since the Fall semester of 2009.

Students receive a grade based on the satisfactory completion of 30+ hours of volunteer service, which must include at least three presentations to local K-12 schools. The students were required to document the hours worked and the tasks completed in addition to writing a reflective, narrative summary of their activities at the end of the semester in order to receive full credit. When these activities do not occur under direct supervision of a faculty advisor, it is advisable to have a trusted student assistant, such as the Chem-E-Car captain, verify the contributions and time logs. Most universities have some level of expectation of work involved for each credit hour. For our university and team, students are expected to log an average of three hours of service per week for each credit hour registered. If all of the criteria are met, the student receives an A in the course, but students are docked a letter grade for each presentation short of this expectation or for every five hours short of the 30 service hours expected. The course is repeatable for credit.

The 2009 ULS Serves grant funded the initial purchase of $1,250 of educational demonstration kits that feature the transduction of energy into various forms as well as providing $1,000 for the Chem-E-Car construction. However, it should be mentioned that Chem-E-Cars do not need to be expensive, and one of our teams qualified for nationals with a car that cost less than $100. After this, the outreach program only requires minor purchases for disposable materials that can be afforded from the Chem-E-Car team's budget or from departmental funds. Travel expenses for local outreach activities have been covered by the students, and while this is not ideal, it is a modest cost compared to the purchase of textbooks and laboratory materials for other courses. Travel expenses for regional conferences in the first few years of the program were funded by a combination of the local AIChE chapter funds, Student Government Association (SGA) funds, departmental funds, and the students themselves. In recent years, our department has been able to fully fund student travel to both the regional and national conferences due to the generous donations of local industry and alumni.

By design, the course and the activities are student-led. Students are required to contact the schools to organize presentation schedules, and the students are primarily responsible for creating the presentations, including the development of any visual aids. The students work with the instructor to make sure the presentations are appropriate for the mission of inspiring students to pursue STEM disciplines and to help articulate what engineers do in our society.

It has been found that recognition through a one-credit course has been an excellent motivator to increase participation in outreach activities that did not exist before the creation of this course. By giving students a small amount of course credit, it gives them a small reward in recognition of their effort and the skills they have learned while committing to a certain level of participation. While many students are content to work on the car on a purely volunteer basis, offering course credit has been successful in increasing the level of contribution of the participants and gives the instructor some leverage to ensure these commitments are fulfilled. It is often difficult for students to commit to the time required to prepare and give presentations unless it is mandatory for a course, even though the students enjoy the outreach experience in retrospect.

Young and Butterfield have emphasized the need to recruit more engineering students to meet future demands, and they have shown how undergraduate mentoring programs can be used to effectively reach K-12 students.[6] The use of the Chem-E-Car has been demonstrated as an effective mechanism for recruiting high school students by the faculty at the University of Tulsa, which held their own version of the chemical car competition with high school participants,[7] where the competition serves to help better define "what a chemical engineer does" to their target audience.[8]

Previous authors have already demonstrated how the Chem-E-Car and the competition can be used to enhance undergraduate courses.[9,10] Faculty at Oklahoma State University have successfully implemented the Chem-E-Car into core chemical engineering courses,[10] which has the additional benefit of allowing the activities to be applied toward ABET accreditation. In contrast, the benefit of using the Chem-E-Car in an elective course is that since it is not mandatory, the voluntary participants are more likely to be motivated to participate, and this provides an opportunity to cultivate excellence in a department by giving the highly motivated students in the department an opportunity to excel.

SURVEY OF SERVICE-LEARNING COURSE PARTICIPANTS

In order to quantify the impact of this program, an anonymous survey of the undergraduate student participants was taken after they completed the course. Eighteen students responded to the online survey, which consisted of 20 questions. Seventeen of the questions were multiple choice responses to questions with integer options of 5—Strongly Agree,

4—Agree, 3—Neutral/No Opinion, 2—Disagree, and 1—Strongly Disagree. The other three questions were free-text responses to gather additional opinions on the program. The 17 multiple-choice questions, tallied responses, and average responses are shown in Table 1.

The results of this survey display the many successes and student development outcomes that have been achieved. By looking at the survey responses, it is evident that the participants have developed a greater appreciation for community service and feel that they have truly made an impact in promoting STEM in their outreach efforts. The Chem-E-Car competition also requires students to develop an appreciation for safety and provides them with an opportunity to practice their technical skills with some level of independence coupled with a minimal, but appropriate, level of faculty supervision. The survey results also show that the undergraduate participants felt that they improved their oral presentation and teamwork skills through this program. This program has been shown to give the students a greater sense of pride in themselves and in their department while helping them build positive relationships with their team.

TABLE 1
Results from Survey of Chem-E-Car Outreach Participants

#	Question:	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Average
1	Do you believe your service has made a positive impact on local high school students?	7	9	1	0	0	4.35
2	Have you developed a greater appreciation for community service?	10	6	1	0	0	4.53
3	Did you learn new technical skills through your participation in this project?	14	3	0	0	0	4.82
4	Have you developed a greater appreciation for safety issues in this project?	10	6	2	0	0	4.44
5	Do you feel this project has improved your oral presentation skills?	9	8	1	0	0	4.44
6	Do you feel more confident in your ability to work in teams on engineering projects?	11	6	1	0	0	4.56
7	Do you have a greater appreciation and understanding of what constitutes effective leadership?	11	6	1	0	0	4.56
8	Do you feel that your participation has helped you prepare for a career in engineering?	10	6	0	1	0	4.47
9	Are you proud of the accomplishment made by yourself and the Chem-E-Car team?	13	4	0	0	0	4.76
10	Has the project given you more confidence in your ability to learn independently?	8	6	3	0	0	4.29
11	Have you developed stronger professional relationships with your peers as a result of this project?	10	7	1	0	0	4.50
12	Do you have a greater pride in your school and department due to your participation in this project?	15	3	0	0	0	4.83
13	Do you feel this project should be continued in future years?	18	0	0	0	0	5.00
14	Has this project motivated you to participate more in AIChE?	9	6	0	1	0	4.44
15	Overall, did you find your participation in the Chem-E-Car and Outreach program to be a valuable experience?	14	4	0	0	0	4.78
16	Is your participation in the project listed on your resume?	12	4	1	0	0	4.65
17	Did/will you mention your work on this project during interviews for a job or graduate school?	13	5	0	0	0	4.72

Considering the skills developed and level of success achieved by the students, it is not surprising that all of the applicants have or intend to mention this work during interviews for work or graduate school, and most of the participants have listed their participation on their resumes at the time of the survey. Many of the activities in the program provide an excellent experience to reference during interviews, which often pose questions related to teamwork, leadership, interpersonal conflict resolution, and overcoming problems outside of coursework that are difficult to answer for other students who have little experience outside of the classroom.

The first of three free-text response questions was an optional request for positive comments regarding the program. A brief overview will be discussed due to space considerations. In the 10 voluntary responses, most comments underscored the points made in this article previously. Notable quotes include:

"The…program provided us with an outlet to do independent research as undergrads which was not previously possible. It was a large contribution to my decision to go on to grad school and pursue a career on the research side of chemical engineering."

"…participating in Chem-E-Car boosted the overall department participation in AIChE events"

"Really developed a strong teamwork ethic. The program definitely brings people together"

"I was just a 'due paying, pizza eating' member of AIChE for 2 years, until…I got on board with Chem-E-Car…. I was actually able to bond with classmates…, innovate, and think outside the box…."

"While I felt…anxiety from public speaking, I feel doing those programs eased that anxiety greatly."

"[In] Every school we visited, the students were very interested in our presentation."

After soliciting positive comments, participants were also asked for criticisms or suggestions for improvement for the program. Two students suggested we should find a way to get more freshman and sophomore students involved. One student suggested that the Chem-E-Car team should be its own club with a budget that is independent of the AIChE chapter. The fourth respondent suggested that individuals should have more defined roles within the team. The final suggestion was that more creative options should be proposed by individuals, presented, and discussed.

The last question asked for additional comments or clarifications of previous responses. To this, there were only two responses that were both general, positive comments regarding the project with one respondent indicating that they had a good experience and would recommend the program with the service project to any incoming student.

BENEFITS

The term "service-learning" defined as learning material while engaged in projects in the community was coined in 1967 although the basic concept has had a much longer history.[11] Service-learning is an active experiential learning process[12] that has been developed at Purdue University as the Engineering Projects in Community Service (EPICS) program.[13] Pearce and Manion have recently shown how service-learning projects can be geared towards contemporary challenges such as sustainable construction.[14] The results from our service-learning program are consistent with previous findings that students gain technical knowledge in service-learning courses at the same rate as in standard courses, but with much larger gains in non-technical skills.[15]

After the completion of the first service-learning course, it became evident that there is a wide spectrum of collateral benefits of such a program. While some of the benefits to the undergraduate participants and outreach target audience are obvious, this section outlines the benefits for the community, the advisor, and the department.

K-12 students and community

Among the primary beneficiaries of this program are the K-12 students visited. While an hour presentation is not enough time to convey a large amount of technical information, it is enough time to provide motivation to students to pursue a career in STEM, which has the potential to change the lives of the student for the better, providing them with improved and more plentiful career opportunities. By combining live demonstrations with a discussion of contemporary energy and environmental issues led by the students' near-peer group of college students, these outreach projects have been found to be highly successful in generating interest and dialogue among the target audience. In the team's first outreach project, one of the high school students commented at the end that "I now have better idea of what engineers do…." —which concisely states the mission of the outreach project. There is also an intrinsic benefit for communities to be better educated in STEM disciplines.

Faculty advisor

The benefits to the student chapter advisor and other participating faculty may not be immediately evident, and since these programs cannot succeed without faculty support, the benefits to the participating faculty should be emphasized. Otherwise, it will be difficult to justify the expenditure of time to the individual faculty member and his or her superiors, especially when engineering faculty need to make important time-management decisions in pursuit of tenure and promotion.

Firstly, it would be difficult to overstate the level of rapport that is built with the students through participating in projects such as these. It is similarly difficult to overstate the importance of this rapport for the faculty member's career. By participating in such projects, faculty members are making a

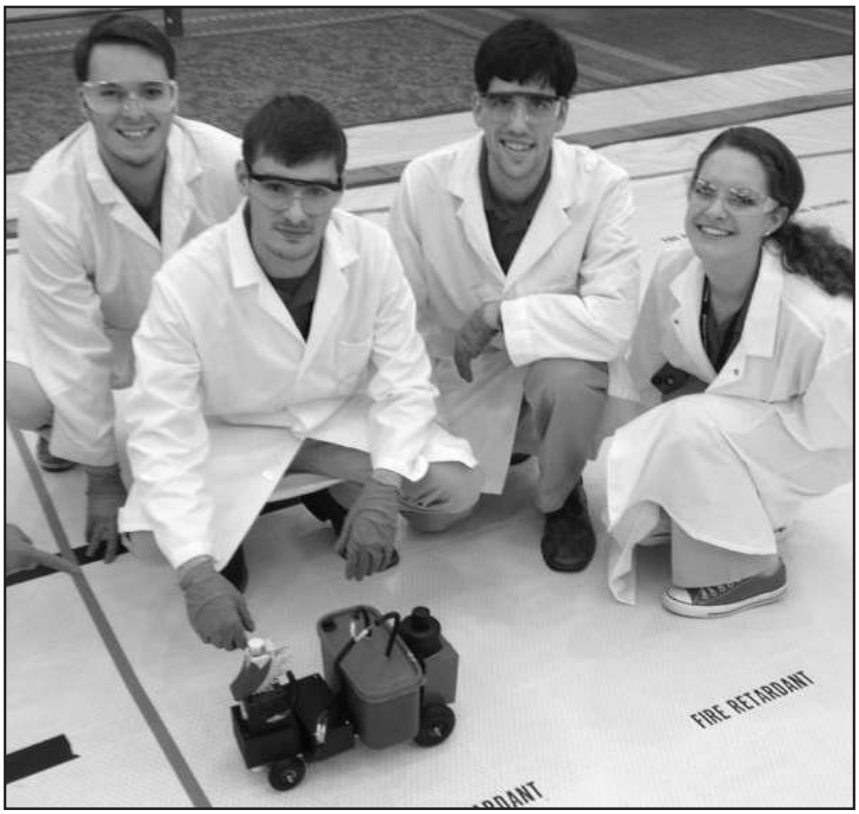

Figure 2. *Chem-E-Car and floor team after a winning run at the 2015 AIChE Southern Regional competition.*

statement that they value the undergraduate students and their education by their investment of time, which is incredibly valuable and finite, and most students realize this and appreciate it. Rapport improves communication, which improves teaching, since the faculty member will be more comfortable talking to students. Initiating or participating in programs such as this one serves to build the advisors' reputation with the students, which can help in student evaluations of faculty—often part of annual evaluations and consideration of tenure. Also, developing positive relationships with students helps professors build their professional network over time as the students graduate and advance in their careers.

After a faculty member has established a reputation for being student-oriented and supportive, there is very little need for active recruitment of undergraduate research assistants, and students will often be willing to volunteer for an advisor who values undergraduate training and education. Furthermore, these projects can be incorporated into research proposals to amplify the broader societal impacts. A history of participation in these projects can also give proposal reviewers confidence that the proposed outreach will actually take place, which may yield a more positive evaluation of the broader impacts.

In the end, there are many personal and professional benefits for participating faculty, and their service does not have to be purely altruistic.

Department and college

In my opinion, when a department shows support for student activities and programs like the one discussed here, it shows a true dedication to the education and professional growth of its students. In turn, these programs can increase the prestige of the department in the local and the national community. Through outreach to local schools, this program serves as a recruiting tool and demonstrates to the local K-12 students that they are valued by the college before they even consider applying. After seeing a presentation from a vibrant and energetic group of undergraduates, it is natural for high school students to want to be a part of the positive group they just watched. The competition and project often attract attention from the local newspaper and television news, which helps the local community appreciate the contribution the university makes. This community support is very important when attempting to solicit donations or when there is a need for political support for higher education.

For such a program to be successful, modest support from the department is essential, which is why recognition of the benefits to the department is important when negotiating the use of departmental time and money. Of these two resources, time is likely the most important, and for the program to be successful, the faculty member should be in communication with his/her head to make sure they agree the commitment of faculty time is worth the investment. Taking a few hours per week to help launch the initiative may seem like a small investment to those outside academia, but it is a significant investment when considering the many demands on faculty time. The department can also help support the program with a portion of its allocated funds or by soliciting funds from alumni or local industries. Furthermore, the department is more likely to receive donations of time and money from alumni if the department invested its time and money on them when they were students.

CHALLENGES

The greatest obstacle in starting such a program is overcoming inertia and starting a program today instead of tomorrow. While the time commitment for all parties is not large by most standards, it is a considerable investment when considering how limited and valuable time is for faculty and students. However, with each milestone—when a functioning car is completed, a presentation is given, a conference attended, or award received—you may expect renewed support from the students, faculty, college, and community.

To be successful, instructors should also make the expectations of the service-learning course clear and hold students accountable. Without setting and maintaining standards of effort, the course could get the reputation of being an "easy A" and attract students looking for an easy grade as opposed to attracting students seeking opportunities for extra service and achievement. Oakes, et al. caution against grading pass/fail.[16] While most students are able to earn excellent marks in this course, it is useful to be able to offer lower letter grades to students who underperform. As recommended by previous literature,[17] students were required to write reflective essays on their experiences to receive full credit in the course. While not conducted in this program, one could increase the rigor of student assessment by including peer evaluations or by grading the deliverables[18] (*e.g.*, the presentations, journals, or reflective essays). The safety of the participants should also be carefully considered. All participants must have appropriate safety training. One challenge is to provide students with sufficient supervision to ensure their safety while allowing them to experiment with some level of independence.

Over the long-term, as with most student groups, a major challenge is to continually attract and involve the underclassmen. Even if a team enjoys great success one year (see Figure 2), you may find that you have an excellent group of seniors about to graduate without enough trained recruits to continue the program, so it is advisable that once a team is established that they start each year with efforts to recruit and train team members for future years. Typically, undergraduate participants will be focused on completing outreach efforts and meeting Chem-E-Car deadlines. Therefore, the advisor should remind the students that they need to continually recruit and train the next generation while participating in the current year. While the upperclassmen are more likely to take on leadership roles, the new recruits can still generate new ideas for the Chem-E-Car and for the outreach program while being trained.

CONCLUSION

While it takes a great amount of determination to take the first step, it has been astonishing how these programs can be self-sustaining, if not auto-accelerating, once they are initiated by a small group of motivated students and a like-minded advisor.

The synergy discovered when combining education, competition, and volunteerism into a service-learning course has exceeded our expectations and has provided valuable professional training for our graduates and greater prestige for the department while serving the engineering community and the local community by performing STEM-focused outreach activities.

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