ChE Students and Automotive Design Competitions: Tips and Techniques for Student Involvement

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Chemical Engineering Design Competitions

Chemical engineering students have several opportunities to participate in design competitions, sponsored by the American Institute of Chemical Engineers and other organizations. Several departments, including that of the authors, have integrated the AIChE National Student Design Problem into the capstone design experience for seniors. AIChE also sponsors design competitions, such as the Chem-E Car competition. This is a fun and lively contest that pits universities against one another in operating a chemically powered toy car. The Chem-E Car competition requires design teams to include underclassmen. These competitions all strive to improve student creativity, ingenuity, and group-interaction skills.

As useful as these competitions are for their targeted student populations, they can seem impractical to many underclassmen students and to the general public. As a result, the authors began a search for design competitions that would meet these criteria:

(1) Underclassmen, especially freshmen, would feel comfortable participating.
(2) The competition would require use of the newest technologies.
(3) The objectives of the competition would be important and easily understandable to the general public.

Bringing underclassmen into the design competition process would provide a sense of accomplishment earlier in their academic careers, which could improve retention. A competition requiring the newest technologies would attract the best and the brightest students to the team. A socially significant competition would provide better outreach opportunities, and could provide recruitment benefits.

Getting Involved: Fuel cell research

Eventually, it was decided to involve chemical engineers in automotive design competitions. This involvement arose from a combination of two factors: (1) a desire to participate in design competitions relevant to underclassmen and the general public; and (2) continuing research in alternate fuel technologies, especially fuel cells.

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Traditionally, Chemical Engineering (ChE) at the University of Tulsa has been a lead institution in petroleum-related research. Over recent years, however, effort has been made to extend this reach into environmentally responsible energy research. One component of this focus has been fuel cell research. As a result, several undergraduates have conducted fuel cell research projects, including some who have designed and constructed fuel cells which power miniaturized vehicles. This vehicle was used in the AIChE Chem-E-Car competition and won 1st Place in the 2004 competition [1].

The application of fuel cells in a design competition led to our proposal to participate in the Challenge X: Crossover to Sustainable Mobility competition. The purpose of this competition is to "[r]e-engineer a GM crossover sport utility vehicle to minimize energy consumption, emissions, and greenhouse gases while maintaining or exceeding the vehicle's utility and performance." The authors' experience in fuel cell research provided a unique chance to apply this expertise to a system with which the general public is quite familiar.

Auto design competitions typically have several schools applying for participation, with very few actually receiving invitations. With this in mind, a multidisciplinary group of faculty was then established to make the formal application to Challenge X. This group consisted of 2 faculty members from Chemical Engineering (the authors of this paper), 2 from Mechanical Engineering, 1 from Electrical Engineering, and 1 from Computer Science. On May 11, 2004, the University of Tulsa was selected to be one of 17 participants in the Challenge X competition. Most importantly, we were told specifically by the competition sponsors, General Motors and the U. S. Department of Energy, that *our application was successful because we involved several disciplines not traditionally involved in automotive competitions – particularly Chemical Engineering*.

ChE Student Participation

The Challenge X competition is a three-year competition with a major milestone each year and various deliverables scattered throughout the years. In this section, the ways in which ChE students have contributed will be highlighted and future plans for these students will be outlined.

Year One (2004-2005)

The purpose of Year One is to select the vehicle architecture and size the various components of the vehicle. Our team had a specific goal of incorporating fuel cells into our design. The first task for the year was to model a Chevrolet Equinox using a new MATLAB-based software package and simulate its operation under a variety of driving conditions. This was accomplished by a multi-disciplinary team. The HYSYS simulation experience of ChE students provided a context for understanding this new software.

Most of the first half of Year One was devoted to modeling new vehicle architecture schemes in the Equinox. Students were required to modify the original simulation models to size and test drive different combustion engines as well as a variety of hybrid-electric designs and fuel cell designs. They could easily see how changes might improve one variable (say, fuel economy), but negatively impact another (say, acceleration). ChE students gained a more visceral understanding of the benefits of using simulations prior to construction because it was equipment they were very familiar with.

One of the priorities for the Challenge X competition is that the modified vehicle improve vehicular emissions and the well-to-wheel greenhouse gas emissions beyond that of the stock Equinox. Chemical engineering students were very interested in this analysis. Argonne National Lab has created GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation), which is a software program that analyzes greenhouse gas emissions for a variety of fuels and vehicle configurations. This software is available as a free download at www.greet.anl.gov. Although the analysis is quite detailed, even freshmen in Chemical Engineering were able to appreciate the output.

The second half of Year One is devoted to developing a control strategy for the vehicle and to constructing the drive train of the Equinox. Several ChE students are playing an integral role on the control strategy team. Other ChE students are involved in building the control systems for the subsystems of the cars. Internship experiences have demonstrated to them that all engineers should understand control systems. ChE controls classes tend to imply that the control valve is the final control element of choice. Students involved in this project are learning that this is only one of many possible final control elements. In addition they are learning that the methods used for control of chemical processes may be applied directly to electrical and mechanical systems. These students are excited about the opportunity to create the control strategy and begin implementing this plan with actual equipment. The size and scope of the project appears to be more appealing to them than the laboratory experiences they have seen so far.

Finally, in Year One, ChE students have taken the first steps to designing a reformer for ethanol that could eventually be used within the vehicle. The students have gathered data from the literature to learn the current state-of-the-art in reformer technology and have initiated contacts with researchers in this field. This information is being used along with HYSYS to create an initial design for a reformer. This technology is very new and, admittedly, ambitious for this project. The reformer may never be incorporated into this competition vehicle, but the students are excited to be trying out the newest technology.

Years Two and Three (2005 – 2007)

During the final two years of the project, the team will implement their plans and designs. GM will award us with an Equinox in June 2005. The TU team will then test and analyze this new stock vehicle before removing the engine and other unneeded components. The students will actually construct the vehicle architecture designed in Year One and implement the control schemes developed during the spring of 2005. Students will also take the reformer design and build a prototype. The hands-on nature of this portion of the project is very exciting to the team. Troubleshooting will be a significant part of this phase.

At the same time, students will continue to refine the models that were constructed in Year One. As the vehicle is constructed and tested, discrepancies between the model and the vehicle performance will be analyzed and the model improved. The ultimate goal is not only to produce an accurate vehicle model, but more importantly to analyze the reasons why they do not agree.

Student Participation

Students are organized based on vehicle subsystem, with most ChE's working on the design of the fuel cell, reformer, and HVAC systems. The continuity of the project is maintained through mentoring, whereby in these working groups, younger students are teamed with an older student. We have made a concentrated effort to attract younger students to the project, as these are the students who will be the "experts" in the years where physical changes are made to the Equinox.

Although this is only the first year of a three-year competition, several important student benefits have been observed. First, students have been exposed to cutting-edge technologies, *e.g.* fuel cells, at an earlier level. During Year One, several freshmen and sophomores are designing fuel cell modules, reformers, and HVAC systems and control systems in multidisciplinary teams, an experience they would not otherwise have. Additionally, students are receiving earlier and more advanced training in software, such as Matlab, Simulink, various vehicle simulators and graphics packages. This not only provides another tool to be used in future coursework, but also provides a unique feature on their resumes when seeking employment.

Transferability

Practically all chemical engineering departments have the necessary expertise to contribute to a HEV design. Ideally, a lead faculty advisor would have a research interest that matches with a technology currently used in HEVs, such as fuel cells, batteries, composite materials, alternative fuels, *etc.* This match, however, should not be viewed as a deterrent to participation. ChEs of all backgrounds have been trained extensively in process analysis; and an HEV is nothing more than a (rather complicated) fuel processing system.

Moreover, it is not necessary to participate in a multi-institutional design competition such as Challenge X to get involved in HEV design and construction. Interested departments could begin with a bench-top powertain, consisting of a small, laboratory-scale fuel cell, battery, and a simple electric motor. Chemical engineering students of all levels could contribute to the sizing and construction in these areas. Advanced students could design a control strategy for this as well.

What is required, however, is a solid commitment to interdisciplinary research. Alignment with a mechanical engineering department is essential for making the necessary decisions concerning vehicle components. An electrical engineering department is extremely useful for designing the control and battery systems.

Outreach

Design competitions such as Challenge X provide an excellent outreach opportunity for Chemical Engineering faculty and students. Public awareness in alternative fuels is increasing with the success of some hybrid-electric vehicles, such as the Toyota Prius. Participating in design competitions such as Challenge X allows the use of an operating vehicle in such outreach activities, which should increase audience interest level, as well as lend credibility to the outreach activity.

Automotive design competitions add several new possibilities to the recruitment of new students. Chemical engineering faculty have long struggled with the "What exactly *is* Chemical Engineering?" question asked by prospective students at recruitment fairs. The availability of a vehicle from a design competition provides an excellent opportunity to demonstrate the breadth of ChE. Participation in auto competitions opens the door to discussions about new, cutting-edge chemical engineering fields such as fuel cells.

Conclusion

To expand student participation in new design projects and to increase public interest in these research efforts, a group of Chemical Engineering faculty and students at the University of Tulsa have participated in an automotive design competition. Although not a traditional avenue of study for chemical engineers, we have found that ChE students at all levels have made significant contributions to the design effort. The emphasis in ChE in process modeling and design is easily incorporated into a vehicle design. Moreover, the involvement of chemical engineers in fuel cell and environmental research makes our involvement in alternate-fueled vehicles a good match.

References

[1] "Rising to the Chem-E-Car Challenge," *Chem. Eng. Prog.* Dec. 2004, p. 57.

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