Melting-Pot Senior Design at OU: 10 Years of Lessons Learned

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Abstract

Ten years of lessons learned from the Melting-Pot Senior Design experience at Oakland University are reviewed and discussed. This unique style of conducting senior design projects brings together all engineering majors in an intense, one-semester, shared, and competitive experience. The many and varied projects that have been explored are described, along with their varying degrees of success. Assessment data are presented, along with strategies for improvement.

Introduction

It has been ten years since the unique senior design experience, which brings together all of the engineering seniors for a one semester, truly multidisciplinary collaboration, was developed at Oakland University. In that time the concept has matured and has become a vital part of OU campus life. Students anticipate the experience, and those within it find that most of the engineering faculty are not only aware but genuinely interested in the current project. The experience always culminates in a public display or competition, and these events have become hugely popular across the OU community, attracting hundreds of spectators each semester.

There are several advantages and disadvantages to implementing senior design projects in this way. Among the strengths is the true multidisciplinary collaborative atmosphere of the exercise, the integration of disparate engineering fields towards the solution of a problem, and the true feeling of accomplishment that often accompanies the end of the semester. Disadvantages include the inevitable struggles with interpersonal conflicts, scheduling and time constraints and the need for more instruction directed towards professional communication skills, both written and oral.

Philosophy

The basic philosophy behind the Melting-Pot approach has changed little since its inception, and has been documented at regional and national design conferences[1-3]. The following are a review of the underlying tenets of this approach.

The senior design experience is supervised by a team of instructors from the OU Electrical and Computer Engineering department and the OU Mechanical Engineering department. Projects assigned by the instructors involve significant mechanical, electrical and computer engineering content. In semesters where students choose their own specific project to suit a given theme, instructors reserve the right to modify the product description to achieve this multidisciplinary goal.

The use of industry-sponsored projects for the senior design experience has, in our experience at OU, been disappointing. Industry-supported projects have been difficult to contract without significant time and resources devoted to the effort, and have been limited in either multidisciplinary nature or technical scope and difficulty. Instructor-assigned projects, appropriate for a focused project taken from start to finish within a single semester, have proven to be far better at achieving the educational goals of the experience.

Students majoring in computer, electrical and mechanical engineering are assigned to each design group, while taking into account individual skills acquired from elective courses, personal experiences and access to off-campus tools and/or workspace. Groups have ranged from 4 to 8 students, with the ideal group about 6 students. One of the students is chosen by the group as a project manager, responsible for organization within the group and communication with the instructors.

The instructors deliberately choose design projects for which they have not explored detailed solutions, and in fact may be outside of their professional experience and expertise. This is an important point, and immediately results in student groups having complete responsibility for their project. The instructors are not "experts" and do not necessarily have "the correct answers" to the technical problems and/or design decisions at hand. Specific technical questions from students are rarely answered by the instructors, and responses consist either of guidance towards a reference or an invitation to learn the answer to the technical question together. All of these practices are devoted to developing and reinforcing the crucial need for life-long learning and self-directed research. However, it is difficult for some instructors to step away from their normal "expert in the room" role and take on more of the qualities of a coach than an instructor. Careful selection of the supervising faculty has minimized this potential problem.

The senior design experience always ends in a public competition or exposition. The use of competition cannot be underestimated when it comes to motivating students busy with outside work, other classes and personal lives. Students do more outside research, spend more time and energy, and look for optimal solutions more when they know they are competing with the other design groups even if all that is at stake are bragging rights. In addition, the OU campus community now looks forward to the senior design competitions at semester end, and we have successfully combined them with open house events and expositions of sophomore design projects.

Budgeting for the project costs of materials and manufacturing has evolved over the years. Initially students bore the cost of prototypes themselves, and projects were developed to be feasible for about $100 per group member, far less than the cost of an average textbook. This requirement was met with a surprising level of cooperation, and the first several semesters ran

smoothly this way. As the senior design competitions became more popular campus-wide, they caught the attention of the OU provost who realized the potential for recruiting and outreach. As a result, money from the OU undergraduate research fund has been made available for prototyping each semester for the last several years, now approaching a total of $100,000. In addition, students must go through the labyrinthine and bureaucratic process of reimbursement for their prototype costs, adding another layer of real-world practice to the senior design experience.

It is understood that many schools would be severely challenged to conduct their senior design experiences in this way. At Oakland University, we have taken advantage of our relatively small size, high level of collaboration between engineering departments and characteristics of our working, commuter students to provide them a multidisciplinary, meaningful, albeit intense, design experience.

Ten years of projects

One of the interesting characteristics of the senior design experience at Oakland University is that, while some projects follow themes established in other semesters, we have yet to do the same project the same way. While this has occasionally placed the instructors in the position of scrambling for a suitable, detailed project description on the day before classes begin, it has been well worth the effort. Considerable value has been generated by having each class of seniors explore different projects and vie in different types of competitions, each with its unique set of constraints, specifications, challenges and rules. This keeps the senior design experience fresh and challenging, for student and instructor alike.

By far the most common type of project, fully autonomous robots have been designed to perform the following specific tasks, always resulting in competitions that place premiums on both speed and precision:

- Race along a taped line that formed a 100-m closed circuit (Winter 2004)
- Climb a rope to the top of a 100-ft tall campus building (Fall 2005, outside)
- Toss ball bearings (2 each of 5 different materials, Winter 2005) or tennis balls (Winter 2012, outside) over a barrier into a bucket
- Climb and move along a rope to drop darts onto a target on the floor (Fall 2007)
- Find and extinguish a candle in a model house (OU version of the Trinity College Fire-Fighting Robot Competition[4], Winter 2009)
- Retrieve a red rubber ball from a model house (Fall 2009)
- Climb stairs, navigate landing (Winter 2010), and line-follow (Fall 2010) with line-crossing (Winter 2011) and retrieve object (Fall 2011)
- Cone-slaloming robots - straight return (Fall 2012), slalom return (Winter 2013), slalom return with payload (Fall 2013), all outside

The projects above denoted as "outside" had their competitions held outdoors on the grounds of the campus, in whatever weather existed at the scheduled time and day of the competition. This very real-world specification has led to some interesting competitions and hard lessons

(especially involving the effects of cold weather on battery life and performance) that will not soon be forgotten.

Several semesters (Fall 2005 - Fall 2006, Winter and Fall 2008) involved the development of "products that might be successful in the global marketplace." Entrepreneurial experts from the OU School of Business Administration guided the students in their product selection and development, and judged the resulting designs on their market potential. It is important to note that the intellectual property developed in any of the senior design projects belongs to the students, not to the instructors or Oakland University.

Some of these student-driven project semesters had specific focuses - The Fall 2006 semester was devoted to developing products requested by the OU School of Nursing faculty and included an infant simulator to help nursing students measure vital signs and a diagnostic test to detect unwanted side effects of medications. The theme of the Winter 2008 semester was to generate and store electrical energy without fuel, inspired by the MIT concept of *crowdfarming*.[5] The following semester focused this concept even further, and developed products that would generate and store enough electrical energy within a 24-hour period to recharge a cell phone.

The project for the Winter 2014 semester sends us off in yet another direction - design, build, test and compete with a device that will sort Skittles® candies by color. The competition will require each team to attempt to sort approximately 1800 candies while displaying the elapsed time and the number of sorted candies dropped into each of eight supplied containers. At this early stage of the semester, it is anticipated that one or more of the ten design groups will complete the sorting challenge in less than one minute.

It should be noted that, even though many of the projects above appear to be small-scale, fun and have limited industrial application, they have all of the technical challenges, design tradeoffs and realistic constraints as any industrial project. The scaling is necessary to be able to complete the project within a single semester, and special emphasis is placed on selecting projects that have the potential to be inherently safe to design and manufacture since limited resources exist for direct supervision during construction and testing. In addition, the technology utilized in these small-scale, fun projects is exactly the same as the technology used in industrial, "serious" projects. Members of the SECS Advisory Board, leaders of some of the largest manufacturing firms in the world, have repeatedly praised the projects and the experience in general as ideal training for their potential employees.

Lessons learned, assessment

After ten years of administering this senior design experience, there have been many lessons learned.

The choice of instructor is critical for this type of experience to be positive for student and instructor alike. The instructor has to be willing to cede the expert role and embrace the unfamiliar role of coach. Students must be given free rein to make decisions and take risks, and experience the consequences of both, without instructor intervention. Feedback from students often express appreciation for this freedom and seldom complain that direction was lacking.

The choice of project is also critical. The project has to be challenging; indeed, the very best semesters have featured projects that appeared impossible to accomplish on the first day of class. The need for challenging projects, however, has to be tempered with the severe time constraint of a single semester. While project descriptions, complete with specifications and constraints, must be spelled out on the first day of class, quite often these have to be flexible, especially if a variation of the project has not been explored previously. Requiring students to forge ahead on a course that is not feasible only leads to frustration and resentment. However, this flexibility can only work one way - instructors can ease the requirements of a too-difficult project but cannot make a too-easy project more difficult.

We find that students are often eager to work, and work hard, on these projects; rarely do we encounter a student only interested in doing the minimum for a passing grade. The technical details of the projects, once a direction has been decided by the group, are often the easiest aspects of the experience for students to deal with. By far, the inevitable interpersonal conflicts and relationships are the most difficult for students to handle. The OU student population is largely commuter, with most seniors employed full-time locally, many in engineering positions. The students with these outside experiences tend to mitigate interpersonal problems within the design groups, since they have become used to notion that you don't necessarily have to like team members to perform well on a project. As a result, it is rare that a design group becomes dysfunctional, requiring instructor intervention to make it successfully through the semester.

Any senior design experience, of course, is a rich source of assessment data, providing a look over the entire program of study. A melting-pot approach is especially valuable, and gives a clear indication of how all of the engineering programs within a school function together. Soon after the implementation of this approach at OU, several difficulties were identified with the engineering programs, all related to the lack of multidisciplinary experiences within them. This led to a restructuring of the engineering core program and the implementation of a sophomore design course, both designed to enhance the awareness of what sorts of problems the other engineering fields could efficiently solve. Once implemented, the overall quality and synergistic aspects of the senior design solutions improved dramatically.

Through the assessment data reviewed it is clear that one aspect of the senior design experience that still needs considerable improvement is communication skills, both written and oral. Students are required to keep a bound design log and submit one-page weekly progress reports, a formal design proposal and a final written report. These reports are often less than fully descriptive, especially during weeks when students are busy with project construction, late-night testing or other classes, and often need several revisions before they are acceptable. Sentence construction, spelling and especially writing to the point are aspects the instructors work on constantly. The student's raw oral presentation skills, seen in the mid-term and final oral presentations, are often considerably better than their written skills. While this is not surprising in this age that relies heavily on oral and video communication, considerable refinement towards professional demeanor and content is always necessary leading up to the final presentation.

The Melting-Pot approach to senior design at Oakland University has been a success over the last ten years. It has provided over 1000 students a true multidisciplinary engineering design

experience, and become a campus-wide event to both celebrate student success and recruit prospective students. While it still has a few areas that need improvement, its potential to provide significant educational value is evident. We are looking forward to the next ten years.

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