THE MELTING POT APPROACH TO SENIOR DESIGN

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Abstract

Senior design courses in engineering programs, in addition to being required for accreditation, are ideal vehicles with which to incorporate and integrate all of the knowledge and skills that students have developed in their academic careers as well as in their extra-curricular lives. However, in spite of the tremendous opportunities to assimilate and develop engineering knowledge and practice, many engineering faculty shy away from teaching these courses, concerned that they have neither the experience nor the time to devote to supervise design projects successfully. This paper provides examples, experiences, perspectives and principles that engineering faculty can use to make their design courses more successful and meaningful, for not only the students but for the instructors as well. We hope to spark the imagination of design instructors to develop more meaningful and interesting projects and to discover the supreme joy there is in teaching design courses.

Introduction

In an effort to provide its undergraduate students with a true multidisciplinary, real-world, team design experience, the senior design courses in computer engineering, computer science, electrical engineering, manufacturing engineering, mechanical engineering and systems engineering of Oakland University's School of Engineering and Computer Science have been combined and are supervised as a single course.

The design teams span all of the represented areas of study and contain from 3-7 members. Three experienced faculty members, one each from the Computer Science and Engineering Department, the Electrical and Systems Engineering Department and the Mechanical Engineering Department, are assigned to the course and provide guidance for their respective areas and collaborate with the administration of the course. In the Winter 2004 semester, 11 design groups are competing to develop autonomous vehicle projects to be used in a Sophomore Design course, to be introduced at Oakland University as early as the Fall 2004 semester.

The specific charge: *Design a programmable mobile robot/vehicle kit that would be affordable for students to purchase at $150 maximum cost. As an application of the kit, design and demonstrate vehicles that follow a line of electrical tape placed on a tile floor.* The kit is to designed to be used in an upcoming Sophomore Design course; that is, for a design course where students would have taken only the first required course in each major.

The competition: Vehicles will be run autonomously around a closed-circuit course up to 300 feet (100 m) long, with several right and left turns, with no turn less than 2 feet (0.6 m) in radius.

Winners will be determined by the minimum time to traverse the course. Obstacles will be placed near, but no closer than 6 inches (0.15 m) to, the course line; touching an obstacle will add 5 seconds to the vehicle's time. Vehicles that fail to complete the course will have 1 second added for every foot (0.3 m) they stopped short of a complete circuit. Teams may attempt up to 3 runs; the shortest adjusted time will be used to determine the competition standings.

This paper includes details of the course administration, grading requirements and policies, specific project guidelines and competition rules.

The "Melting Pot" Approach

The main feature of our approach to teaching design is what we call our "melting pot," where all of the senior design courses within the School of Engineering and Computer Science (there are five, spanning electrical, system, computer, mechanical and manufacturing engineering and computer science) are scheduled for the same day and time slots, but in separate rooms. At least one of the rooms scheduled must be large enough to accommodate all of the students at once and is used periodically throughout the semester for mass meetings and oral presentations.

It is important to note that although these five design courses meet at once and are administered in common, they are not combined administratively into a single course. The autonomy of the three instructors (one from each of the electrical and systems engineering, computer science and engineering and mechanical engineering departments) to assign grades and be instructors of record is not affected. This careful arrangement provides for the background and knowledge of three experienced engineering professors to supervise and act as resources for the student design projects.

In bringing together all of the senior students, we ensure that we have a sufficiently large and diverse pool of skills and background with which to form teams that can successfully handle almost any design project.

Student Design Teams

Student design teams are assigned by the instructors, with the sole purpose of arranging successful teams. On the first day of class students fill out a form that asks for information on their educational field, skills they have developed, other educational background and experiences, extra-curricular skills, and access to outside sources of space and tools that the team may use to build, test and optimize prototypes. The information on these forms is used to assemble the design teams, each of which has the range of skills and resources that the instructors feel are important for the teams to be successful. Other interpersonal aspects, such as friendships, personality likes and dislikes, gender and personal schedules are given little to no priority. It is noted here that other theories of assigning optimal groups exist, see for example (Oakley, *et al*, 2003 and Stibiak & Paul, 1998). Students are provided resources with which to deal with inter-team conflicts and the instructors are available to help resolve group friction if it should develop (Oakley, 2002).

In the Winter 2004 semester, 11 design teams were formed and given a common project, each with representation from the Computer Science and Engineering Department, the Electrical and

Systems Engineering Department and the Mechanical Engineering Department and are composed of 6-7 students. The teams were assembled in such a way that at least one member in each group had access to off-campus physical space and tools and at least one had computer-aided analysis skills. Two other design groups were formed to work on other projects for student organizations and sponsored research.

Choice of Design Project

Successful design projects must begin with choosing a suitable problem, one that can be successfully solved within the required time, whether a single semester or as part of a two-semester sequence. In the melting pot approach, design projects are chosen that span all the engineering disciplines represented in the course enrollment. Little thought is given to specific assignments or academic experiences that students might have previously had. The most successful projects often result from design problems that initially appear to students, and even the instructors, to be impossible to solve, especially within the required time or budget. The educational value is in the project itself, in the journey of learning new skills and knowledge, rather than reproducing a known result.

It is not required that the project outcome be known in advance to the instructors. Much educational value can be gained from choosing a project in which the instructor has no specific background or previous knowledge. As students watch how the instructor learns about the project areas, as they listen to the questions asked of them, as they receive requests for more information and suggestions for change, they see first-hand how engineers tackle new tasks, learn and become familiar with new technology and applications. Don't be afraid of proposing a design project that you don't know how to solve. On the contrary, allow yourself to learn from the project and allow your students to see and hear you learning along with them.

In an effort to provide "real-world" design experiences, some schools have successfully pursued industry-sponsored design projects. Sponsored projects have many advantages: the pressure is taken off the instructor to choose design projects, revenue is generated for the school or college, and future employment contacts can be made between the students and industrial liaisons. However, a different sort of educational experience results from such arrangements. In performing sponsored industrial projects, the focus is appropriately on the deliverables of the contract; that is, the devices, equipment or reports that have been specifically contracted. The educational value of the project experience immediately becomes less important, to both faculty and student alike, than the business of contracting student labor. Students need a safe place to learn to how to make mistakes within a design project, like chasing dead ends or burning out electronic components, and to learn how to recover from those mistakes. These skills are more difficult to develop if there is the added pressure of needing to provide deliverables to an outside company at the end of the semester. This additional pressure often results in squelching creativity and leads to safe, easy, boring and predictable design solutions. Contracted industrial projects have their place within a modern engineering curriculum, but not as the sole vehicle with which to teach design principles, time management or creativity.

It has been our experience that students can easily bear the cost of developing design projects themselves. Of course, if the design project is contracted by an outside company or will be used within the school (to improve laboratory facilities, for example), then it is paid for by the company or institution. However, the vast majority of design projects performed at Oakland University are funded by the students themselves, without problems or complaint.

In the Winter 2004 semester, students were given the task of designing a kit to be used in a upcoming Sophomore Design course, which itself will also utilize the melting pot approach. This kit, which can cost no more than $150 in lots of 100, must be able to be assembled into a vehicle that can autonomously follow a line of electrical friction tape placed on the floor over a closed circuit of up to 300 feet (100 m) long. Several aspects of the problem statement are important to note. None of the three instructors in this semester had previous experience with this type of project, although the fourth author listed had supervised similar projects in a previous semester. The requirements of the project and the resulting competition (see below), including the cost limit, were stated as to effectively eliminate the purchase of available model kits that perform similar functions. The physical size of the vehicles was controlled by the specifications in order to lower the cost and the physical space necessary for construction.

Using projects centered on function-performing vehicles is ideal for senior-level, melting-pot design experiences. Variations on this project that have already been suggested by students and faculty include vehicles that search for parking spaces and perform parallel parking, suggestions for other autonomous robot applications (such as the Trinity College Fire Fighting Home Robot Contest, www.trincoll.edu/events/robot/), and even teams of autonomous robots that cooperate to perform a function, like playing a game of soccer or other team activity. All of these project suggestions are truly multi-disciplinary in nature and can be fully developed and demonstrated by groups of seniors within a single semester.

Never Answer a Question

Students are given full responsibility for their design solutions. The instructors are present to act as resources, or to direct students toward resources. As such, few questions directed at the instructors are answered in a direct way; the vast majority of inquiries are answered with questions such as “What do you think?” of “How could you find out if that will work?” It must be understood that the educational value of the design experience is in the experience itself. The true value is in the journey towards the goal, it is not within the goal itself. The expert model, where the instructor is the omniscient keeper of knowledge and students apply only what they are told by the instructor, has little place within a design course. The pedagogical shift that faculty must make from expert in lecture courses to fellow learner or questioner in design courses is very difficult for most professors but is crucial for the development of competent, flexible and independent engineers.

The Importance of Competition

Motivation of students today can sometimes be a challenge. We have found that it is more effective to let students motivate themselves, and the easiest way to do this is to provide an umbrella of competition for the project course. Students do more independent work, question assumptions and specifications more closely, analyze and research more, spend longer hours and exert much more effort if they think their labors will gain them an advantage in a competition, even if all that is at stake are bragging rights.

For the Winter 2004 semester, the student-designed vehicles will run autonomously around a closed-circuit course up to 300 feet (100 m) long, with several right and left turns, with no turn less than 2 feet (0.6 m) in radius. Winners will be determined by the minimum adjusted time to traverse the course. Obstacles (cardboard toilet paper or paper towel rolls) will be placed near, but no closer than 6 inches (0.15 m) to, the course line. Touching an obstacle will add 5 seconds to the vehicle's time. Vehicles that fail to complete the course will have 1 second added for every foot (0.3 m) they stopped short of a complete circuit. Teams may attempt up to 3 runs; the shortest adjusted time for each group will be used to determine the competition standings. Modifications of any kind can be made to the vehicle between competition runs. In order to qualify for the competition, each vehicle must successfully negotiate a curved portion of the track while supporting an additional payload of 15 lb.

Overall Course Organization

A specific application of the melting pot approach to senior design courses can be illustrated with the experiences at Oakland University in the current semester, Winter 2004.

At the first class meeting, forms were distributed to collect student profiles for team assignments, students were introduced to the design project and were encouraged to start researching (via the Internet) similar types of projects. By the second class meeting, design groups had been formed and emailed to all of the students in class and were posted on the class web site. Most student groups had met and began researching design idea by the second class period. The class web site

http://personalwebs.oakland.edu/~latcha/me492/syllabus.html

was also used throughout the semester to distribute frequently asked questions and answers concerning the rules of the competition, the schedule of milestones and guidelines for preparation of oral and written reports..

Student groups meet weekly with the team of instructors, submit informal written progress reports and provide an informal oral progress report to the team of instructors. These meetings, which typically last only 10-20 minutes each, are an opportunity for the instructors to see physical progress made on prototypes, to touch base with the groups and observe how the members are functioning within the groups. It is important that the instructors do not divulge the progress or details of designs of the other groups during these meetings. The informal progress reports are worth 10% of the final course grade.

Before the groups could start purchasing components, they were required to submit a written proposal of a design, with initial engineering and cost analyses. These proposals, due in the third week of the semester, required a plan for the project instead of merely buying parts and trying to get to them to work together. The project proposal is worth 15% of the final grade.

At the midpoint of the semester, formal oral progress reports were presented using PowerPoint to the entire class and any interested visitors. These oral presentations were worth 15% of the final course grade. At the end of the semester, final written reports worth 25% of the final grade will be submitted and oral presentations (worth 25%) will be made to the entire class and any interested visitors. On the last day of the class the competition will be held; standings in the competition are worth 10% of the final course grade.

Conclusion

The conclusion to this paper cannot be written until the competition is held on April 15, 2004. After that date, the complete conclusion can be found at

http://personalwebs.oakland.edu/~latcha/

At this time, we can make only brief and general observations.

As compared to previous projects supervised by the fourth author, the melting pot design groups currently seem to be about 3 weeks ahead of teams of computer engineering students working without the other engineering fields represented in their groups. As of this writing (the middle of March, 2004), two of the 11 teams have vehicles which can successfully negotiate the line of tape and are actively pursuing strategies to increase speed while maintaining tracking accuracy. The remainder of the groups is within days of similar milestones. The division of labor with respect to engineering field was, as predicted, easily accomplished, but there has been a surprising amount of field crossover. We have observed in several groups that mechanical engineering students are teaming closely with the computer scientists and engineers to program the microprocessors as the electrical and systems engineering students are dealing mainly with sensor arrays and packaging. Power supplies have been a challenge for all of the groups, with several novel ideas (that will be included in the final conclusion) being implemented across the groups.

The current melting pot experience at Oakland University is an unqualified success. The concept and practice has thus far been very enthusiastically received by both students and faculty.

References

"Turning Student Groups into Effective Teams," Barbara Oakley, Richard M. Felder, Rebecca Brent, Imad Elhajj, *Journal of Student Centered Learning* (October, 2003).

Strbiak, C., & Paul, J. (1998). *The Team Development Fieldbook: A Step-by-Step Approach for Student Teams*: McGraw-Hill Primis Custom Publishing.

"It Takes Two to Tango: How 'Good' Students Enable Problematic Behavior in Teams," Barbara Oakley, *Journal of Student Centered Learning*, Volume 1, Issue 1, Fall, 2002, pp.19-27.