MELTING-POT DESIGN AT OAKLAND UNIVERSITY

Michael A. Latcha, PhD, Oakland University, Rochester MI, USA
Michael A. Latcha is an associate professor in the Department of Mechanical Engineering. His teaching and research interests include machine design, design for reliability and modeling multi-bodied dynamic systems.

Debatosh Debnath, Oakland University, Rochester MI, USA
Debatosh Debnath is an assistant professor in the Department of Computer Science and Engineering. His teaching and research interests include digital systems design, computer architecture, and microprocessor-based systems design.

Imad Elhajj, American University of Beirut, Beirut, Lebanon
Imad H. Elhajj is an assistant professor in the Department of Electrical and Computer Engineering. His teaching and research interests include multimedia networking, sensor and computer networks, Internet security, robotics, human machine interfacing and medical systems.

Edward Gu, Oakland University, Rochester MI, USA
Edward Gu is a professor in the Department of Electrical and Computer Engineering. His major teaching and research areas include electric machines and control, industrial electronics, robotics and nonlinear control systems.

Richard Haskell, Oakland University, Rochester MI, USA
Richard E. Haskell is a professor in the Department of Electrical and Computer Engineering. He is the author of 15 books and has taught numerous undergraduate and graduate courses including courses in microprocessors, embedded systems and digital design using VHDL.

Melting-Pot Design at Oakland University

Abstract

Over the past 3 years the School of Engineering and Computer Science (SECS) at Oakland University (OU) has developed a philosophical strategy with which to deliver a meaningful, truly multidisciplinary and comprehensive capstone design experience. This strategy, dubbed the "Melting-Pot" approach, brings together all senior students majoring in electrical, computer, systems and mechanical engineering as well as computer science and, after assignment into multidisciplinary design groups, charges them with either a common task or with the challenge to develop a meaningful project that might be successful in the global marketplace.

The essential features of the Melting-Pot approach to senior design are:

- Senior design teams are supervised by at least three professors from the Computer Science and Engineering, Electrical and Computer Engineering, Industrial and Systems Engineering, and Mechanical Engineering departments.
- Design teams are assigned considering only the engineering fields, experiences and special skills of the students.
- The design projects assigned have not been solved, or even explored in depth, by the instructors.
- Questions from students are seldom answered; they are always treated as opportunities for research.
- The design experience always ends with a public display and competition
- The experience includes a significant communication component (reports, presentations, posters).

The success of this approach to senior design has been well received by students, sponsors, industry partners and accreditation evaluators alike. As a result of the high quality of the projects developed in this experience, Oakland University has begun to fund the prototype development of the projects as part of OU's undergraduate research initiative. We have begun to partner with colleagues in the School of Business Administration to further develop the marketing aspects of the design projects and have recently been approached by outside companies to work on industrial projects.

In order to incorporate the feedback data obtained in our assessment process, the SECS core curriculum was recently revamped. One of the goals in changing the core curriculum was to correct deficiencies observed in student background and understanding in the senior design experience. As a result, a sophomore level design course has recently been instituted, incorporating many of the Melting-Pot principles. We anticipate that introducing students to meaningful and multidisciplinary research design experiences earlier in the curriculum will better prepare them for both the senior-level experience and professional practice, as well as positively contributing to retention.

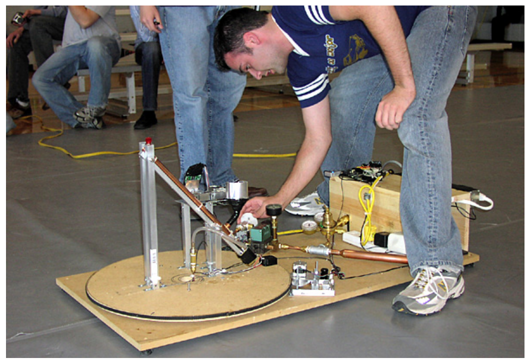
This paper tracks the progress of the development of the Melting-Pot approach, documenting both mistakes and successes from its initial offering to the present. Specific assessment data will be shown along with the actions taken to incorporate the feedback and measure the improvements. Special attention is given to the development, assessment and improvement of the sophomore design experience.

Introduction and Background

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, 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 "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, systems, computer, and mechanical engineering and computer science) are scheduled for the same day and times, 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.



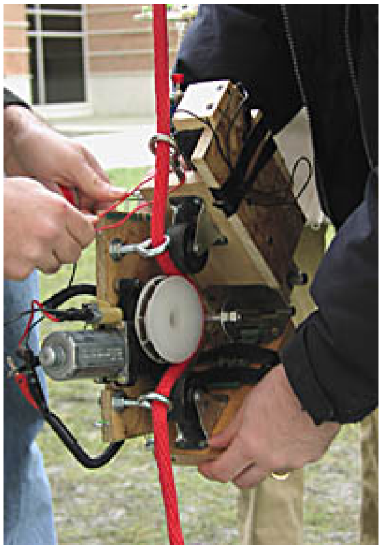
It is important to note that although these five design courses meet at once and are administered in common, they are not combined administratively into a single course. The autonomy of the three instructors (one from each of the electrical and computer engineering, computer science and engineering and mechanical engineering departments) is not affected. This 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 provide 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 and test prototypes. This information is used to assemble the design teams, each of which has the range of skills and resources that the instructors feel are important 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[1] and Stibiak & Paul, 1998[2]). Students are provided resources with which to deal with inter-team conflicts and the instructors are available to help resolve group friction, should it develop (Oakley, 2002[3]).

Choice of Design Project

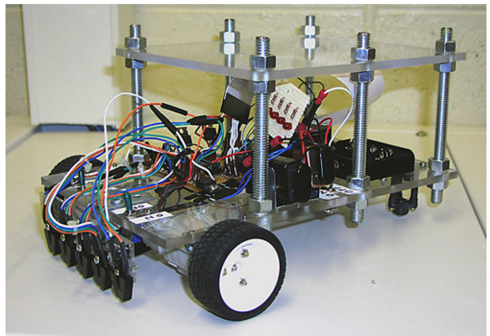


Successful design projects must begin with choosing a suitable problem, one that can be successfully solved within the required time, whether a single semester or as part of a two-semester sequence. In the melting pot approach, design projects are chosen that span all the engineering disciplines represented 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.

Significant 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 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.

Funding the Design Project Prototypes



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 have been funded by the students themselves, without problems and with minimal complaints. The course has no required textbook, and when each student in the team pitches in an amount equivalent to the cost of a textbook, the total amount is typically sufficient to fund the project.

In the Winter of 2005, the large number of visitors the design competitions drew to campus, and the high quality of the projects on display, attracted the attention of the upper administration, most notably the Provost. With a little effort on our part, the rules for OU's Undergraduate Research initiative were stretched to accommodate the semester-long schedule of the senior design course, and the University has since graciously provided funding of $1000 per student group for the last three semesters to defray the costs of developing the project prototypes. While it is understood that this level of funding is not guaranteed to continue indefinitely, it is deeply appreciated and is a tangible commitment of the University to this effort.

It is important to note that the University does not make a claim to the intellectual property developed as part of these projects. Unless prior arrangements have been made (such as in the case of an industry-sponsored project), the students are free to patent or to market their design projects after the semester is over, and they are put in contact with the OUIncubator, OU's recently-started business incubator program, to facilitate this opportunity.

Never Answer a Question… Well, Seldom Ever.

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 the experience itself. The true value is in the journey towards the goal, it is not the goal. 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 some professors but is crucial for the development of competent, flexible and independent engineers.

The Importance of Competition

Motivating today's students can sometimes be a challenge. We have found it to be more effective to let students motivate themselves, and have found the most effective 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.

Overall Course Organization

At the first class meeting, forms are distributed to collect student profiles for team assignments, students are introduced to the design project and are encouraged to start researching similar types of projects. Immediately after the first class meeting the design groups are formed, emailed to all of the students and posted on the class web site. Most student groups begin to meet and research design ideas by the second class period. Each student group also selects a project manager or team leader.

Student groups meet weekly with the team of instructors, where they submit informal written progress reports and provide informal oral progress reports. 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.

Before the groups are allowed to begin purchasing components, they are required to submit a written proposal of a design with initial engineering and cost analyses. These proposals, typically due in the third week of the semester, require an initial plan for the project instead of merely buying parts and trying to get to them to work together.

At the midpoint of the semester, formal oral progress reports are presented to the entire class and any interested visitors. During semesters with head-to-head competitions, no secret or particularly clever ideas need to be divulged during these progress reports. At the end of the semester, final written reports are submitted and fully-detailed oral presentations are made to the entire class and any interested visitors. Typically, the competition is held on the last day of class or the day before the first day of the final exam period.

Design Projects Undertaken

In the seven semesters that the melting-pot approach to senior design has been implemented at Oakland University, the types of design projects have varied tremendously:

- **Winter 2004 –** Design and compete with a vehicle that follows a line of electrical tape on the floor. The vehicle had to autonomously negotiate the closed-circuit track (up to 100-m long) in minimum time, was assessed time penalties for hitting obstacles, and had to demonstrate its ability to function while also carrying an additional 15-lb weight, all limited to a total cost of $150.
- **Fall 2004 –** Design and compete with a vehicle that autonomously climbs a rope to the top of the 8-story (30.5 m) Science and Engineering Building, ascending and descending in minimum time while announcing the distance from the ground every 3 meters. The competition was to take place in whatever weather occurred on December 2, 2004 in Rochester MI. Teams were limited to a total cost of $250.
- **Winter 2005 –** Design and compete with a wireless device that would throw 10 0.5-in diameter balls (consisting of 5 different materials) over a 0.5-m high barrier into a bucket, which could be seen only via a single webcam placed on the far side of the barrier. The bucket was randomly moved, within predetermined limits, between competitors. The competition was based on the number of balls delivered into the bucket, divided by the product of the time required to throw the 10 balls and the cost of the device.
- **Fall 2005, Winter 2006, Fall 2006, Winter 2007 –** Student teams in these semesters were challenged with the task of designing a product that "could be competitive in the global marketplace." The 41 products that have been developed are incredibly varied and include:
    - infant simulator with respiration and pulse for training nursing students
    - automated pool/spa chemical care system
    - do-it-yourself zone-controlled HVAC system
    - hydro-generator system driven by wave motion
    - system for serving and cooling bar/restaurant beverages
    - mural printer
    - automated/interactive medication dispenser
- **Plans for Fall 2007 –** In the Fall 2007 semester, the student groups will be charged with developing independent autonomous vehicles that must cooperate to perform some common task, such as arranging themselves in predetermined patterns (similar to a marching band). This will necessarily require that the student teams cooperate with each other to determine communication methods and protocols, and the competition will be based on how well each individual vehicle performs both alone and in cooperation with the others.

Assessment Results and Improvements

The main assessment tool in the School of Engineering and Computer Science (SECS) is the *External Evaluation of Program Outcomes*, where evaluators not associated with the course are invited to peruse student work and decide the level at which the work demonstrates the stated program outcomes. Feedback from the *External Evaluations* initially showed that while the reviewers approved of the multidisciplinary aspects of the projects, the level of rigor in analyzing the designs left something to be desired. In addition, the integration of the various engineering disciplines was uneven. Student feedback showed a significant level of unease working with students in other fields, and a general lack of knowledge of not only what the other fields were supposed to accomplish, but even what was possible in the other fields.

The SECS at Oakland University was founded on a systems approach to engineering, and it was clear from the data that we had moved away from that ideal. Two years ago, driven mainly from the feedback we had received in the senior design courses, we completely revamped our core engineering program, returning to an integrated systems approach. This new core curriculum culminates in a Sophomore Design course that combines programming microprocessors and classical mechanics, leading to a multidisciplinary design project that requires computer control of an electromechanical device. It is still too early to tell if this fundamental change in the core program will improve the performance of the students in Senior Design, but based solely on the quality of the projects seen in Sophomore Design, it is clear that we are training students to be more creative, and more clever, earlier in their careers, which can only lead to better results in the future.

Based on assessment feedback, more emphasis is now placed on analysis, but not to the exclusion of clever ideas that seniors do not yet have the skills to analyze completely, especially considering the extreme time constraints. This is a fine line to walk: to require analysis of the designs, but not to restrict the design solutions to come from the limited set of cases that seniors are able to thoroughly analyze. Industrial relevance of the designs is the responsibility of the students to explore, and initial steps have been made to include students from the OU School of Business Administration to provide marketing and business plan components to these projects.

Conclusions and Future Plans

By all accounts, the melting-pot approach to capstone design projects has been a huge success at Oakland University. Part of the success of this approach has been the commitment of the instructors to incorporate the assessment feedback immediately into the process by which the projects are selected, and to act only as coaches, mentors and resources during the design experience. Other reasons for the level of success are the financial commitment of the University to funding the prototype costs, and the numerous other administrative supports in terms of scheduling and many other seemingly small but important details. Building this program has been a most challenging and pleasant journey, and we are always looking forward to the challenges and projects of the next semester.

Bibliography

1. "Turning Student Groups into Effective Teams," Barbara Oakley, Richard M. Felder, Rebecca Brent, Imad Elhajj, *Journal of Student Centered Learning* (October, 2003).
2. Strbiak, C., & Paul, J. (1998). *The Team Development Fieldbook: A Step-by-Step Approach for Student Teams*: McGraw-Hill Primis Custom Publishing.
3. "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.