Faculty Involvement in the Electrical Engineering Senior Design Program

Michael N. Kozicki, Ph.D., FNAI
Professor of Electrical Engineering and Senior Design Coordinator
School of Electrical, Computer and Energy Engineering
Arizona State University

Email: michael.kozicki@asu.edu    Phone: 480 965 2572

Summary

The Senior Design program in electrical engineering is a project-based capstone experience for seniors, with emphasis on teaming, open-ended value-driven project outcomes, and the development of soft skills in the participants. Projects provided by faculty are particularly attractive as, in addition to exposing the students to “real world” engineering and research problems, they typically come with access to resources and professional mentorship and allow faculty to work with talented individuals that they may eventually bring into their research teams as graduate students. This document describes the electrical engineering capstone program and discusses effective faculty involvement.

Background

Across many engineering curricula, the project-based capstone or "senior design" experience is usually the last obstacle before graduation but it is anything but just another box to tick on the student’s schedule of classes. The senior design project is likely to be the one thing that differentiates the student from all the other people with similar degrees and similar GPAs that are going for the same dream job so it better be chosen carefully and done well. Capstone course content also tends to fulfill many of the curricular requirements for accreditation, which leads to extensive syllabi that range far beyond purely technical issues. College and university program accreditation bodies such as ABET, guided by the engineering profession through institutes and national academies, mandate certain student outcomes, such as those listed for engineering degrees below:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

3. An ability to communicate effectively with a range of audiences.

4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

In modern engineering programs, these topics are frequently introduced at various points throughout the curriculum but should be emphasized in capstone design classes, which are the culmination of the degree experience and the point at which technical and soft skills are usually brought together and practiced in order to provide the best professional preparation possible.

The Senior Design Program in Electrical Engineering

The “Senior Design Laboratory” in Electrical Engineering is a two-semester sequence (EEE488 and EEE489) comprising a capstone project and supporting lectures for Electrical Engineering seniors that are both on campus and completely online. The program includes technical and soft skills components with emphasis on the “entrepreneurial mindset”, designed to provide complete professional preparation. Note that this course couple fulfills Literacy and Critical Inquiry, as well as all ABET accreditation requirements.

− During the first semester (Senior Design Laboratory I - EEE488), teams are formed, projects and professional/technical mentors are selected by the students, and the first phase of the project is completed. The major deliverable at the end of the first semester is a comprehensive proposal that includes details of the background research, tasks, timelines, budget, preliminary feasibility studies, and planned project work and deliverables in the second semester.

− In the second semester (Senior Design Laboratory II - EEE89), the plan is fully executed and the "product" (device/system/service) is built-out, tested, evaluated, improved, and presented. The major deliverables are a comprehensive report (or in select cases a business plan) covering all the work performed since the start of the project and a final demo in a “trade show” atmosphere that is open to the public.

The students are encouraged to form their own teams, which typically comprise four electrical engineering seniors but collaboration with students/teams in other engineering disciplines (e.g., biomedical engineering) and even in units outside of engineering (e.g., space and planetary science) is also possible if the arrangement meets program requirements.

The lecture material includes discussions on product development, technical communications, soft engineering issues, project economics, project management, ethics, graduate school, life-long learning, critical thinking, manufacturability, intellectual property, company structure, entrepreneurship, the environment, sustainability, engineering in society, political issues, health and safety, business plans, globalization, as well as presentations by guest speakers.

Project Definition

There are generally three sources of project concepts - the students themselves, faculty/research staff, and industry partners. The concepts are vetted by the course coordinator using criteria a - d below. Regardless of the origin of the project concept, the students are required to take full ownership of the work and are totally responsible for its success or failure.
In our experience and given the ABET student outcomes listed above, a good capstone project should have the following elements:

a. Embrace an open-ended non-trivial problem that involves multiple aspects of the student’s learning experience in their chosen degree (in this case Electrical Engineering) as well as new knowledge acquired during the course of the project (addresses outcomes 1, 6 and 7).

b. Have clear and positive value in that it meets a well-defined need or want with consideration given to negative impacts (addresses outcomes 2 and 4).

c. Be appropriate for a team of students working with appropriate time and resource (money, equipment, facilities) constraints (addresses outcome 5).

d. Involve frequent communication across understanding/experience/training levels, involving not only the “standard” methods of technical information delivery (reports, presentations, etc.) but also more condensed forms of social interaction such as blogs, tweets, short videos, and “elevator pitches” that can be used to quickly explain and promote the work to non-technical audiences (addresses outcome 3).

Resource constraints fall into the categories of time, money, and equipment/facilities. Project duration is always two semesters and the students are expected to use planning tools and techniques to help them use this time wisely. The University expects at least nine hours per week of dedicated effort on capstone projects outside of the classroom, which translates to more than 1,000 person-hours of work for a four-student team over the course of the project. Project funding is available through the School, with $100 to $200 available for small expenditures and larger amounts (up to several thousand dollars) being accessible following the submission of a cost proposal that must be pre-approved by the School.

The project choice is completely up to the students themselves, which means that some good project concepts may go untaken if they are not presented to the students in a way that makes them attractive. During project selection, the students are encouraged to consider the following:

− Stay within your competence boundaries. Recruit team members that bring the competence that you need to be successful or join teams already formed that would benefit from your particular skills and talents.
− Take a hand in defining the project scope and stick to it. Scope creep will result in you running out of time and money before you can get anything useful done!
− The geographical (and temporal) separation of online students from one another leads to additional challenges. Whereas this is not generally a problem for software development, hardware work will require multi-site strategies that include having duplicate systems at each location (e.g., you all have your own Raspberry Pi kits and daughter boards) or a lot of FedEx work. This is doable with sufficient pre-planning and an appreciation for the issues beforehand.

**Mentoring**

All teams are required to have a mentor, a professional who will guide them in their project work and ultimately is responsible for a significant portion of their technical grade (see later). First and foremost, the mentor is not a supervisor, as the team is responsible for their own management, but is instead a
professional guide for the students, some of whom may have little or no actual engineering/industry experience.

"Mentoring is a process for the informal transmission of knowledge, social capital, and the psychosocial support perceived by the recipient as relevant to work, career, or professional development; mentoring entails informal communication, usually face-to-face and during a sustained period of time, between a person who is perceived to have greater relevant knowledge, wisdom, or experience (the mentor) and a person who is perceived to have less (the protégé)." - Bozeman, B.; Feeney, M. K. (October 2007). Administration & Society. 39 (6): 719–739.

Mentors should offer advice and encouragement born of their own extensive experience to keep the teams focused and on track. In most cases, mentors should also be able to help the teams with the technical aspects of their projects, pointing them to the necessary resources that they themselves cannot provide directly, including helpful domain experts. Mentors may also get involved with team dynamics, being called-upon to resolve intra-team disputes when they arise.

There is an expectation that the mentors will meet with their team once per week, either in person or by using teleconferencing. The mentors should also be provided with all reports and assessments that the students are required to produce as part of the class.

Assessment and Grading

In both EEE488 and EEE489, the class grade is split equally between technical work and communication/soft skills. The communication and soft skills assessment includes video reports, weekly blogs/online notebooks, formal presentations, progress reports, participation quizzes, a proposal (at the end of EEE488), a final report (at the end of EEE489), and a final public demonstration of the project (totaling 50%). The technical grade is split between the grade that the mentor provides (40%) and a “balancing grade” (10%) that is provided by the teaching team (class coordinator plus teaching assistants) with input from the team members via an intra-team evaluation.

– The mentor grade is based on the team’s technical competence, as well as their ability to plan and work together. Other aspects such as frequency and productivity of meetings/contact with the mentor, enthusiasm, team cohesiveness, and capability for independent thought and action, are also considered. These grades are requested at the end of each semester using a letter/plus-minus scheme (e.g., B+, A-, etc.). Each team member may receive an individual grade if the mentor is comfortable doing this, otherwise a single grade may be granted to the entire team.

– The difficulty/balancing grade is used to level the scores for project difficulty, utility, and level of completeness across all the teams in the program. It is also used to adjust individual team member scores using information from the intra-team evaluation.

We encourage the student teams and mentors to co-develop a grading contract during each semester. This contract should define the conditions that must be met in order for the team to be granted a particular technical grade. For example, an A grade might only be granted if the team meets regularly with the mentor, passes all planned milestones/attains the stated goals for the semester, and are generally enthusiastic about the work, with lower grades being granted for lower attainment.