Session 2425

Senior Design as a Transition from Academia to Industry

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Abstract

In its eighteenth year, the Electrical Engineering Senior Design course sequence at the Milwaukee School of Engineering has evolved from an engineering-focused course set, to one with design at the center of a process focused on fostering professional growth. Successful design is treated as the natural outcome of a combination of technical preparation and a set of professional skills. As a result, the student grows from an academic individual to a professional one, accomplished in working with business and industry methods. The changes have been made in response to changes in the students and their needs as graduates.

In the nine-month experience, the first portion focuses on team building, leadership development, problem identification and certification, and design feasibility determination, through differing communications requirements. In the latter parts of the course sequence, in parallel with the technical aspects of the design project, the setting of milestones, managing the project, and performing and documenting engineering work are augmented by key professionalism topics. These span the range from "selling oneself" and selling the project concept, to considering global competition concerns.

Our "course within a course" style also includes guest specialists working with the students on topics such as safety, ethics, standards, resume and interviewing techniques, and even professional behavior. A "trade show" with a prototype and poster competition completes the course's professional experiences. Employer response to the efforts has been very positive and encouraging.

I. Introduction

Throughout the Bachelor of Science in Electrical Engineering (EE) program at MSOE, design is strongly integrated into many courses. These projects are generally short-term, and involve individual or two-student teams. The projects lead to the major capstone design experience, Senior Design, which is a three-quarter course sequence: EE-407/8/9. While all EE students are required to take this course sequence, often interdisciplinary projects are undertaken, and the teams can include other engineering students: computer, mechanical, software, etc. Over the 18 years of the existence of this course, it has evolved due to changes in employer needs, student traits, technology, and the faculty's understanding of the needs of the graduates.

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II. The Changes in Senior Design

There are many different styles of capstone design courses that can be taught[1,2], and the original approach of EE-407/8/9 aligned with many of them.

In its original form[3], the course focused primarily on technology: EE design, prototyping, and testing methods. It was a "traditional" course in project design. The goal was to have the student teams bring to bear technical topics from their many prior lecture and lab courses on a project of interest. The benefits of having a team were primarily in the additional workers available to get the job done.

As the years progressed, the course changed significantly, as a result of differing demands of business and industry, and changes in both students and technology. It is common knowledge that students now communicate differently than those in even recent years. They depend greatly on 21st century technology with cellular phones, Instant Messaging, email and the like to maintain social contacts. Such communications often substitute for face-to-face interaction, a substitution that can have profound effects, especially if the engineering student is at all introverted (certainly not uncommon). What we are seeing is students limiting their practice and honing of "soft" skills. Such behaviors may be the natural outgrowth of their experiences and time spent "on the computer" as children.

Employers are now reporting that our EE students do not always interview well, and that their social skills and awareness are not as developed as they could be. Specifically, they often don't make eye contact, seem self-centered and unaware of others, and lack the ability to make "small talk" that is not related to their immediate goal. Whether this is a result of the new technology-based methods for communicating is unclear. In any case, their level of social or soft skills is impacting their success, regardless of (or in spite of) their technical knowledge and abilities. As has always been the case, and is true at any age, they need good skills in the category of "Plays well with others."

In EE at MSOE we have specifically addressed written and verbal communications skills program-wide, in an effort to better understand the problem, and to provide solutions[4]. Our EE program's approach to communications improvement is both deep and wide, spanning all four years of the EE program, and including courses taught by professors of engineering, sciences, English, social sciences, and humanities. It provides a challenge for the professors of today. And it would be a fascinating and disturbing irony if EEs themselves have developed communications technologies that actually inhibit their own social growth and development.

Employers (including our EE Industrial Advisory Committee) further state that teamwork is more important than ever before, and that this teamwork can include interdisciplinary teams. By interdisciplinary they can mean combinations of various types of engineers, such as electrical, computer, software, and mechanical. But they can also mean that teams are combinations of strengths, such as technologists, communicators, managers, and customers.

Naturally, the Senior Design course goals include traditional technological ones as well. The detailed use of the students' technical background to solve a problem is expected. They must work in a team to identify a problem, research solutions, arrive at a suitable one, and design and implement it. But this problem solving is conducted in an atmosphere influenced heavily by the demands of teamwork, project management, time management, and communication.

The general goals of Senior Design address the above concerns.

III. The Goals of Senior Design

The changes in business and student traits cited above have meant that EE Senior Design has needed to change over the 18 years it has been taught. Nearly a complete generation of students has experienced the course, and it would be expected that changes would have been made. The changes have been driven by technological advances, professional practices, a changing business scene, and student traits and characteristics.

As a result, the goals of Senior Design have evolved to include the following:

1. Help students with the transition from academia to industry. In their first three years in college, the students usually work alone: in class, taking notes, doing homework, studying for and taking tests, writing papers, giving presentations, and managing their own time. Typically, in the laboratory the student will partner with another student. However, the dynamics of a team of two does not at all compare to that of a larger group. Hence, while this overall approach is traditional and works well for the individual in an academic setting, it can be a shock when the student needs to work in a larger team in industry. Considerable time is spent in the first-quarter EE-407 course on team building, and this continues throughout the year.

2. Understand the difference between a problem and a solution. This is one of the more poorly understood concepts of seniors coming into the course. Often on "day one" they say, "We have decided on a project – we want to design an infrared data link to connect a computer to a printer." They are disappointed to find out that this is a solution to a problem, and that they have not considered what the actual problem is, much less what other solutions are available (802.11b network? Other wireless method? How about a 25-foot cable strung over the ceiling?). The business impact of launching a solution "because it is cool" is discussed in depth.

3. Build and work in teams. Sitting together in class does not make a team, of course. In EE-407 we often spend 20-minute portions of the lecture having them solve and present solutions to various innocuous problems, such as "What portion of the U.S. is covered in grass?" or "Find 10 ways to measure the speed of a car." They must work in their teams to get this accomplished. The problems and their solutions are unimportant – the key reason for doing these exercises is to build their team relationships. They (and their professor) will see who is a natural leader (usually very obvious), who is a follower, and who would rather be elsewhere. The team members learn to depend on each other, see what strengths each one has, and find out about each member's preferred method of interacting in a group.

4. Undertake a long-term project, set milestones, and succeed. They are required to use Microsoft Project to schedule their tasks. Furthermore, they must set milestones for their team, and also for each team member. They will make mistakes, and must determine ways to recover from them. A significant portion of their final grade depends on success.

5. Communicate. Requirements, detailed below, include numerous communications activities – reports, memos, poster, briefings, formal presentations, and design reviews.

6. Act in a professional manner. This covers many topics from communications to decision-making, to interaction with their professor and others. Sometimes they will ask, "Do we have to get dressed-up for the presentation?" Our answer is, "Do what you believe will make the impression you want." They will sometimes make a bad judgment because of this, but they learn quickly when they see what their classmates are doing.

IV. The Specifics of Senior Design

Quarter 1 – EE407. In EE-407 the teams comprised of four students are formed, and they select one of two experienced Senior Design professors, based on their preferences. Generally, the class divides evenly between professors with 6-7 teams per professor. In class they must sit with their team, with attendance taken in each of the three lectures per week. At times, both sections are brought together for a combined lecture if the topic is appropriate, such as the course introductory material, a guest lecturer, etc.

Each team selects a team leader, for at least the first quarter. After several weeks, that team leader is asked to submit a memorandum detailing their leadership style, and how he/she has dealt with conflict in the team. After much discussion about team strategies, the teams are asked to determine how their tasks should be assigned – is an individual a technical specialist or instead associated with a particular task? That is, some teams consider each member to be a specialist in a technical area such as software, hardware, analog electronics, or interfacing. Alternatively, some teams consider their members to be specialists in task areas, such as management, parts selection and procurement, electronics design, or test engineering.

Project design is treated as a process, in which they must achieve various milestones: define a valid problem, research the problem, use two ideation methods to generate a list of possible solutions, reduce the list to the three best solutions, and determine the feasibility of the three. They must do a simple patent search (at www.uspto.gov), identify competing products, and discuss the problem with potential customers. The students sometimes conduct surveys to determine customers' desires. During this stage, the Fogler and LeBlanc textbook[5] is used as a guide to the design process described above. It details the specific methods used in each portion of the process.

In order to determine feasibility and write their feasibility study report, they must determine a preliminary set of specifications, and a list of "musts" and "wants." The "musts and wants" are from the viewpoint of the customer, and each "want" is given a weight based on its importance to the customer. The three competing solutions are judged according to the degree to which they satisfy the "wants."

The feasibility study report describes the above process, and culminates in a recommendation to the engineering manager (their professor) that a specific set of resources needs to be committed to the project – personnel, time, money, and equipment. Their schedule for success is detailed in the form of a Gantt chart.

Industry sponsorship of the projects is allowed, as long as the academic goal of successfully completing Senior Design takes precedence over competing business desires. Such sponsorship is not uncommon, and is very much appreciated. The students work with industry engineers, and get a good understanding of the need to be precise, detailed, and specific.

Sometimes the teams do not perform the feasibility determination in enough detail. That is, they may omit the calculations to determine whether the proposed technology is up to the task, in terms of data rates, memory requirements, battery life, and so on. But with close faculty interaction, these difficulties can be minimized.

In addition to the feasibility study report, there are other requirements and components that determine the course grade. Students conduct a peer team design review (in front of the entire class) at midterm, and a formal presentation at the end. Each student receives his/her own grade on the formal presentation. There is a midterm exam as well. Each student must maintain an engineering notebook, and these are collected and graded. Finally, there is a component to the grade that depends on individual and team effort.

Quarter 2 – EE-408. The structure of EE-408 and EE-409 are very similar to each other. Rather than have formal classroom meetings with the whole class, the interactions take two forms. First, there are (at a minimum) bi-weekly meetings with each team. In these meetings, the students must bring several items – their engineering notebooks, any partial prototypes, and a special form that lists, for each team member, three things: their promised achievements since the last meeting, what was actually achieved, and what they promise to achieve by the next meeting. If promised achievements (milestones) were not met, the particular student must provide a written memorandum explaining why. The resulting impact on the project scheduling and Gantt chart must be documented and agreed upon by the entire team.

The second type of meeting occurs each week. This is a two-hour combined lecture to all students. These lectures comprise a "course within a course," dealing with topics not typically found in other courses in their backgrounds. The two Senior Design professors may talk on subjects such as quality, electronic construction techniques, or conflict management. Guest lecturers from on- or off-campus may talk on interviewing techniques, professionalism, globalization, safety, consulting engineering, the transition to management, etc.

During this quarter, the students are expected to complete the detailed design and start the process of ordering parts, and assembling and testing portions of their designs.

There is no midterm test, but the other course requirements are similar to EE-407. At the team meetings, the professor gives encouragement, helps with technical or "red tape" problems, and holds the teams accountable for any observed shortcomings.

For the project work, there is a special large laboratory set aside solely for EE Senior Design, containing four workstations, each with modern, networked test equipment. For the most part, the students use it as a work and meeting room. To some extent it is a social gathering place, but that also serves a very useful purpose.

Quarter 3 – EE-409. The design should be nearly complete and testing should be taking place. The grading and course structure are similar to EE-408, but instead of the formal presentation, a Senior Electrical Engineering Design (SEED) Show takes place on the last day of final exam week. Since the next day is graduation, parents, siblings, friends, professors, and other students (juniors, it is hoped) will attend. The professors who served as advisors visit this "trade show" display of the projects, assess them, and use this information in determining the "prototype" portion of the grade. A final design report is required. Additionally, the teams are required to produce a poster, of a style suitable for a poster competition. In fact, the poster is part of the grade. MSOE provides for the printing and laminating of the color posters, which are ultimately framed and placed on the hallway walls of the engineering building.

The team projects often span a wide range of interests and technologies. Projects have included a robot to aid in practicing the sport of fencing, an Internet-enabled heart monitor to allow remote access to home-bound cardiac patients, a hand-held nutrition analyzer with bar code reader to scan food packages, the electronics package for a Formula racecar, an Internet-connected vending machine, and a submarine. Students are allowed to select projects of interest to them, within reason, and this helps to generate excitement and motivation in the team.

V. Assessment and Observations

The changes that have been made to Senior Design have met with an encouraging and positive response from our industry and business partners. The efforts being made to improve communications and professionalism are having an observed positive effect, with the students seeing how others consider this to be an important item in their growth as engineers and people.

Teaching the course is a challenge for the professors, as might be expected. The professors need to have a background that is wide and varied, and that can complement that of each other. They must have policies, both formal and informal, that match closely. Hence, the course sequence is team taught to a very substantial extent.

The student teams, having to work together for nine months, find out a great deal about themselves and each other. Personalities sometimes clash, and nearly every type of good and bad human interaction has been observed. The professor must maintain close contact to see if any changes are occurring in the team internal relationships and intervene if necessary. We encourage the teams to solve such problems on their own, but to feel free to ask us to help if necessary.

Each year several teams have a member who feels he or she can "coast," with the others doing the work. It is amazing to the professors how blatant this can be. Appropriate discussions ensue. Each quarter we ask each team member to assess his/her teammates by allocating an imaginary

$100,000 bonus between all four teammates. This generally confirms the perception of the professor of the degree each team member is contributing to the project.

The nature of Senior Design has also changed significantly in a technical sense with time. Integrated circuits in DIP or through-hole packages are being replaced by surface-mount types, and this is creating a prototyping problem. We are now allowing pre-made subsystems or “demo boards” to be part of a prototype design. For example, designs needing a radio link may use the common postage-stamp RF boards for a transmitter and receiver. Printed circuit boards (from Internet PCB vendors) are encouraged, but not required.

VI. Conclusions

During the 18 years of teaching EE Senior Design, changes have occurred in not only technology, but also in student traits, student communications preferences, and the needs of business and industry. The Senior Design course sequence has evolved to meet these changing needs by surrounding the traditional “design project” with a framework focusing on professionalism. This enhanced approach to design fits well with the needs of our business and industry partners, and serves to smooth the students’ transition from academia to the professional world of electrical engineering.

Incorporating the beyond-design topics that focus on professional skills is important for various reasons. Not all students will be, or want to be, designers. The broader exposure serves all the students regardless of their future career paths. Our survey taken at the beginning of each Fall quarter shows that many want to be in other engineering roles, from research to sales and management. The additional topics will help them. Further, the added professional skills are of much greater significance for the success of our graduates than the learning of a few more technical facts.

Over the years we have noted that it is not always the high-GPA students who do well in Senior Design. Often it is the students who have a drive and a passion to work on their projects which results in the best success. We believe our Senior Design approach complements the range and variety of operating styles found in a normal group of students.

Bibliography

1. Farr, J., et. al, “Using A Systematic Engineering Design Process to Conduct Undergraduate Engineering Management Capstone Projects,” *Journal of Engineering Education,* vol. 90, no. 2, 2001, pp. 193-197.
2. Doty, R., and Williams, S., “A Practice-Based Senior Design Experience,” *Proc. 2002 ASEE Annual Conf. and Exposition,* June, 2002.
3. Born, R., “A Capstone Design Experience for Electrical Engineers,” *IEEE Trans on Education,* vol. 35, no. 3, Aug. 1992, pp. 240-242.
4. Wikoff, K., Friauf, J., Tran, H., Reyer, S., Petersen, O., “Evaluating the Communication Component of an Engineering Curriculum: A Case Study,” Proc. 2004 *ASEE 2004 Annual Conf. and Exposition,* Salt Lake City, UT, June, 2004.
5. Fogler, H.Scott, and LeBlanc, Steven E., *Strategies for Creative Problem Solving*, Prentice-Hall, 1994.

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