# Achieving EC2000 Outcomes in the Capstone Design Via Structured Industry Advisory Board Involvement

**Kathleen A. Kramer**
**University of San Diego**

**Abstract**
The capstone design sequence was selected as a focus for the structure of the activities of an industry advisory board. The focus on the capstone sequence provided both a framework for ongoing industry involvement and an improvement in student project results. Activities included supplying input on changes in the approach to the design process within the capstone sequence, such as team structure and expected milestones. Industry advisory board members were actively solicited for comments and input relating to most of the EC2000 outcomes the capstone project is intended to demonstrate. The result of this involvement was to enhance not only the capstone design experience of the students, but also the overall effectiveness of the advisory board and its commitment to the program.

## Introduction

At many EAC/ABET-accredited programs, the capstone design experience has become a significant part of the process used to ensure the achievement of many of the a)-k) outcomes required of each program under EC2000. In the wake of EC2000, many engineering programs have also created advisory boards for their programs to represent their industry constituency.

According to EC2000, "Each engineering program for which an institution seeks accreditation … must have in place…a process based on the needs of the program's various constituencies in which the objectives are determined and periodically evaluated" [1] This requirement that the process be based upon the needs of the program's own constituencies is, effectively, a requirement that each program identify its constituencies and have some means of getting periodic input from them on their needs. The constituencies identified by almost all programs include: 1) students, 2) industry, and 3) alumni. While programs that are in place certainly have access to students and usually have access to alumni, obtaining input from the industry constituency can present difficulties and was, prior to EC2000, often done on an *ad hoc* basis.

The need to have a process in place that included input from and evaluation by the industry constituents has prompted many programs to establish [or re-establish] an industry advisory board. Periodic meetings of such boards can provide a regular process by which input from the industry constituency is determined and evaluated, supporting continuous improvement of the program. The overall result is that there are now significantly more advisory boards supporting engineering programs than would have been found prior to the year 2000. In some cases, these boards have membership that represents only the industry constituency, while others are created with membership from the industry, alumni, and even student constituencies.



*Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*

Prior to 2000, the main focus of such advisory boards was to provide prestige and resources to the program or institution. The "ideal" member would be a CEO, a corporate vice president or other highly ranked individual with a major engineering corporation. This model served many major and some minor universities well. Frequently, however, the membership was dominated by retired and semi-retired men who might not have done actual engineering work for many years and who might be from industries no longer employing many engineers locally. While such individuals do have much valuable advice to offer, they can be limited in their ability to provide input to and evaluation of the program's development of the specific skills that are in demand by employers.

In 2001, the University of San Diego Electrical Engineering Advisory Board (EEAB) formed. Its members were intended to represent the program's local industry and alumni constituencies. This new advisory board was selected to be composed of electrical engineers who were members of local industry. Rather than trying to maximize the number of CEOs or corporate vice presidents, the "ideal" member had 5-10 years of experience and worked as a lead engineer on projects, but was not so senior as to be removed from the current hands-on technical work of his or her company. Result is a board member who is less likely to give big money in the short term and more likely to have current, hands-on knowledge that is directly beneficial to the students. Once it was established, the EEAB met once each semester and its initial focus during the first year or so was the establishment of the program educational objectives.

The educational objectives of the USD Electrical Engineering Program are to develop graduates who:

1. Are able to apply their electrical engineering and broad academic backgrounds in their professional and personal endeavors.
2. Can adapt to evolving job responsibilities.
3. Can contribute effectively on a team and provide leadership in their professional careers.

**Table 1 – USD Electrical Engineering Program Educational Objectives**

Meeting at least twice per year helped the advisory board to maintain regular contact with the program and to develop a team approach to its work. Once the educational objectives were established, however, there was no need to continue to update them twice per year. A new focus of activities was needed. In 2002, the EEAB agreed to make a significant commitment to applying their current, industry-based perspective to enhancing the capstone design sequence.

## Role of Capstone Design in Meeting Program Outcomes

The "(a) – (k)" outcomes [1] that programs must demonstrate that graduates meet are shown in Table 2. While the capstone design experience is obviously one that should contribute to outcome c) "an ability to design a system, component, or process to meet desired needs," several other outcomes, particularly those less easily quantified, are typically expected to be demonstrated within the capstone design experience of accredited programs. It is not uncommon to see the capstone of a program listed as demonstrating all of the "(a) – (k)" outcomes. The changes in what must be demonstrated within the capstone courses at ABET-accredited programs has significantly increased the work involved for many instructors involved in teaching these courses. At University of San Diego, for example, the capstone course sequence is expected to demonstrate all of the "(a) – (k)" outcomes, except for (j).

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| Engineering programs must demonstrate that their graduates have:<br>(a) an ability to apply knowledge of mathematics, science, and engineering<br>(b) an ability to design and conduct experiments, as well as to analyze and interpret data<br>(c) an ability to design a system, component, or process to meet desired needs<br>(d) an ability to function on multi-disciplinary teams<br>(e) an ability to identify, formulate, and solve engineering problems<br>(f) an understanding of professional and ethical responsibility<br>(g) an ability to communicate effectively<br>(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context<br>(i) a recognition of the need for, and an ability to engage in life-long learning<br>(j) a knowledge of contemporary issues<br>(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. |

**Table 2 - ABET Criterion 3: Program Outcomes and Assessment**

## Advisory Board Involvement in Capstone

Majors in electrical engineering at USD must complete a two-semester capstone design sequence, Electrical Engineering Design and Practice I and II (EEE 191 and EEE 192), in order to complete their degree. The program itself is structured as a 9-semester undergraduate program requiring 151 semester units that culminates in a dual-degree BS/BA. The length of the program means that the capstone sequence is completed over the spring and then fall semesters or, in some cases, over the spring semester and then the extended summer term. Increased advisory board involvement in the capstone was planned beginning in Fall 2002 and affected sections of EEE 191 and EEE 192 during Spring 2003, Summer 2003, and Fall 2003.

The involvement of the EEAB within the capstone sequence included:

1. Continuing to schedule EEAB meetings to coincide with capstone presentations
2. Changes in structure of the projects and the role of design reviews
3. Ideas for project and project mentoring
4. Lectures and activities on professional topics

## Scheduling of Advisory Board Meetings

EEAB meetings continued to be scheduled to coincide with capstone presentations, allowing members to participate in the reviews by asking questions during the oral presentations and filling out evaluation forms. This scheduling provides a regular, expected schedule and reason to keep in contact with members regularly throughout the year. The students and the instructor directly benefit from the input that industry representatives can provide. Other benefits include promoting industry involvement in projects and their individual commitment to program by increasing contact with students and involvement in curriculum.

**Changes in Course Structure and Use of Reviews**

Course structure changes were made under the direction of the instructor beginning in Spring 2002 to allow for more input from local industry into the selection of projects. Formerly, students were assigned to teams of 3-4 students early in the first semester of the sequence and then either assigned a project or charged with developing their own project that would be completed over the course of the two semesters. The most significant revision in structure was to revise the first half into a competitive project proposal phase that culminated in proposals by teams of 2-3 students, about two-thirds of whom would be expected to be approved to go to the next phase. After the mid-semester review, during which industry advisory board representatives were expected to participate, students on projects not given a "green light" were reassigned to other teams. EEAB member and faculty reviews of written and oral proposals were, as planned, very significant in the decision between the competing projects.

In Spring 2002, there were 10 initial proposal teams, 9 with two students and 1 with three students. After the proposal review, 7 of these proposals were approved to continue and students from the other 3 teams were re-distributed, creating the final 7 teams each with three students. There were interesting results observable in comparing summaries of reviews and rankings by faculty with those of the roughly equally sized group of industry reviewers.

The comments on proposals tended to have different qualities depending upon whether they were made by faculty and industry representatives. With faculty, the comments were usually very short and were concerned with how appropriate technical aspects were for a capstone project in that discipline of engineering, including how well students had planned and understood the involved tasks. With industry, comments on marketability and comparisons to commercially available items and the need for more detailed specifications, analysis, and tests before spending money were more common.

The overall rankings of the 10 proposal teams also differed between the faculty and industry reviewers. There were a total of 11 reviewers – 6 faculty and 5 from industry. The same review forms were used and reviewers gave scores of 1 to 5, 5 being highest on several technical aspects that were combined to an overall technical score. The resulting ratings for Teams "A" – "J" are shown in Table 4. The rankings that resulted are shown in Table 5. Overall, faculty ratings were much more variable than advisory board members'. The most significant differences in ratings were for teams "B" and "G." It is possible that they resulted from faculty biases that resulted from knowing the students on those teams in other courses; other explanations are also certainly possible.

| Team | A | B | C | D | E | F | G | H | I | J | overall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Industry | 3.19 | 2.98 | 3.81 | 3.31 | 3.30 | 3.90 | 3.15 | 2.66 | 2.99 | 3.34 | 3.26 |
| Faculty | 3.66 | 4.10 | 3.71 | 3.84 | 3.01 | 4.28 | 3.27 | 2.76 | 3.32 | 3.34 | 3.53 |

**Table 4 – Average Technical Merit Ratings by Faculty and by Industry for Proposals**

| Ranking | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th |
|---|---|---|---|---|---|---|---|---|---|---|
| industry | H | E | D | F | G | A | I | C | B | J |
| faculty | H | B | F | E | A | D | C | I | G | J |

**Table 5 –Technical Merit Rankings by Faculty and by Industry for Proposals**

EEAB members were, subsequent to the proposal phase, invited to each of three more reviews: the preliminary design review held at the end of the first semester, the critical design review held just past midterm in the second semester, and the final design review held on the last class day of the fall semester. Review forms at each of these directly pertained to aspects of ABET outcomes (a), (b), (c), (d), (e), (g), and (k) and results were reviewed as part of the process within the program to assess these outcomes.

**Involvement in Selection of Professional Topics**

Given the "ideal" member was actively working on engineering projects at a likely employer, the advisory board was consulted as to what shortcomings they saw in general with the student capstone projects [2-3]. Industry representatives provided input on what practical technical topics and professional issues would be appropriate for inclusion in various class meetings, with individual board members often agreeing to provide the demonstration or be available for consultation. The following lecture topics were the result.

- Marketing-Driven Product Development
- Top-Down Design
- Patents
- "Advanced" Team Issues
- Capabilities and Use of Xilinx FPGAs
- Capabilities and Use of DSP boards
- Using PCB Express

From the student perspective, the lectures on team issues were the most effective of the professional issues while the demonstration on designing and ordering printed circuit boards was the most valued of the electrical engineering technical topics, influencing the majority of the student projects to include such a board in their final demonstration. The students also reported that there were too many such lectures, and, in the next iteration of the course, they will be reduced by about one-third to include those regarded as more effective.

**Project ideas and project mentoring**

Industry-based projects are the most typical method of involving industry in the capstone, and the majority of universities report at least some use of such projects within their capstone design courses [4-6]. At many institutions, this is the sole source of senior projects and can provide students with an ideal capstone experience. At USD, only about 20% of the recent projects have been industry sponsored projects. Those that have been industry-sponsored have generally been quite successful, but such projects have also generally required greater up-front approvals and planning by the industry sponsor.

In an effort to solicit more quality industry-based projects, EEAB members were given a sample one-page description two months in advance of the start of the capstone sequence. For those projects that were not industry-based, individual board members agreed to mentor individual projects that had been approved to continue past the proposal stage.

Only small increases were observed in the number of industry-based projects; board members cited difficulties including the requirement that it be a team project, timelines dictated by the academic calendar, and the need for the project to be both appropriate to the discipline and include true design.

Project mentoring by EEAB members was encouraged and explicit assignments were made and agreed upon by most of the board members. In those cases where the involvement was observed to actually occur, the "mentor" provided student teams with contacts that might provide equipment or even financial support. Despite assignments, significant "mentoring" was not observed to occur on an ongoing basis unless the projects had originated from the board member himself or herself.

**Conclusions**

The involvement of the EEAB within the capstone sequence included: 1) scheduling of EEAB meetings to coincide with capstone presentations, 2) changes in structure of the projects and the role of design reviews, 3) ideas for project and project mentoring, and 4) lectures on professional topics. The EEAB increased activity within the capstone sequence did enhance the effectiveness and overall involvement of the board with the program it serves. The framework of board activities within the capstone sequence successfully included each of the board members in at least one formal design review and provided an ongoing agenda of activities for the board as a whole. The scheduling of activities also provided regular contact with members throughout the year. Other benefits included promoting industry participation in projects and the individual board member's commitment to the program by increasing contact with students and involvement in curriculum.

Assessment of the student work within the capstone sequence included faculty and industry reviews of student work on four different occasions over a two-semester sequence: proposal (with written report and formal presentation), preliminary design review (with written report and poster-demonstration), critical design review (with written report and formal presentation), and final design review (with written report and poster-demonstration). In addition to the industry and faculty reviews, student self-assessment included ratings of team performance and contributions using Team Developer [7] and a separate instrument with more qualitative reflections on team members' contributions. Industry advisory board participation in the assessment of student work contributed to the achievement of several of the EC2000 outcomes, particularly (c), but also the majority of the (a)-(k).

Industry advisory board involvement resulted in some changes in structure – in particular, the designations of "preliminary design review" and "critical design review," along with some modifications of the associated project milestones. The industry reviews of the student work on each of the four occasions provided valuable input to both the instructor and the student teams, including ratings that were noticeably different from those produced by faculty. Industry input was found to be more of great quantity and quality at the initial proposal review and at the critical design review, both of which involved formal presentations.

All seven of the projects approved after the proposal stage were evaluated by both industry and faculty as being of sufficient difficulty and technical merit, a significant improvement from past evaluations of this aspect of the design project when the projects were proposed by the student teams rather than assigned by the instructor. The most significant benefits were in the early stages of the project, where upcoming reviews and the competitive nature of the proposal phase stimulated much more effort than was typical in the past.

Some areas that were indicated as being less satisfactory to the students in their evaluations included having to achieve more milestones earlier and having to tolerate more critical reviews than they had previously experienced. Results from the most recent sections are being applied to the students within the course in 2004, where efforts are being made to change the student expectations with regard to these aspects of the capstone experience.

## Acknowledgements

The author would like to acknowledge the important contributions by Chuck Pateros, Member of Technical Staff at ViaSat Inc. and Chair of USD's Electrical Engineering Advisory Board. Significant contributions were also made by board members Jarvis Tou, Scott Denton of Applied Micro-Circuits Corporation, Keith Pflieger of Trellisware, Inc., Terry Hache of Copper Mountain, Cathleen Quick of Sun Microsystems, and Donald Reed of SAIC.

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KATHLEEN A. KRAMER is an Associate Professor of Electrical Engineering and currently serves as Director of Engineering at the University of San Diego. Her teaching and research interests are in the areas of digital systems, communications systems, and data fusion. She received her MS and Ph.D. in Electrical Engineering from the California Institute of Technology, and her BS in Electrical Engineering from Loyola Marymount University.