‘Techniques for Advising Undergraduate Students on Senior Engineering Design Projects

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Abstract

The objective of this paper is to describe techniques that will help new faculty members (or faculty members new to teaching design) be more effective as advisors to undergraduate students working on senior engineering design projects. While senior students may be highly creative and motivated and possess the engineering science background required to make good design decisions, they often need help in bringing structure to their effort. Even though much progress has been made at Mercer recently in integrating design within the engineering science curriculum, students still have difficulty applying their engineering science understanding to the task of making good design decisions. This is particularly true when the project is multidisciplinary and the functional requirements include those that are difficult to quantify. Often, the student’s experience with the aspect of design methodology dealing with feasibility and merit analysis has been limited to classroom exercises. When an actual device must be designed, built, and tested, and the students must interface with a real client (which are both features of Mercer University’s design course sequence), the use of decision analysis tools becomes much more complicated than simulated problems used in academic exercises. All of this means that the students need help in pulling the engineering science and design methodology together in an environment made even more challenging by budget and time constraints. This paper describes several techniques that the authors have found effective in their experience as advisors of numerous senior engineering design projects. These techniques serve as mechanisms to aid in “coaching” or “mentoring” the students through the design process. The authors believe that they have found an effective balance between helping the students structure their efforts while still allowing the students to make and learn from their mistakes.

I. Introduction-- Understanding the Challenges

The Mercer University School of Engineering has a two-quarter senior capstone design sequence. The purpose of this sequence is to have the students integrate their engineering science knowledge with design methodology, decision analysis, and project management. This can be very challenging for the students. The open-ended nature of a substantive design project presents special problems for students who have spent most of their time and energy in engineering science courses which have emphasized analysis. Recent progress in spreading design across the curriculum has helped to remind students how analysis can be used to predict a system’s performance. Unfortunately, it is difficult for the students to be competent without a fair amount of structure while they are simultaneously trying to learn fundamentals. Therefore, the scope of the “open-endedness” of a meaningful senior design project is much greater than what they have seen before. This is desirable since typical design challenges for which the students are being prepared (beyond the schooldoors) are themselves extremely open-ended.

Mercer's National Engineering Advisory Board, a group of senior technical executives from industry, has strongly encouraged the use of multidisciplinary design projects in our program because they represent the types of design challenges that exist today. Engineers are called upon to interface intelligently with others-outside their area of expertise. For the student, having to tackle a multidisciplinary effort requires new team building skills that have not been developed in the engineering science courses of the sophomore and junior years.

Another aspect of the "real world" that is easily replicated in most academic engineering design programs is the need to operate in accordance with tight time and budget constraints. There is not enough time in either today's extremely competitive global economy or in a two quarter course sequence for very much "wheel spinning." Making progress while staying on track is essential for survival in both the "real world" and the academic contexts. With proper "mentoring" by the instructors, the students can overcome the challenges and have a very rewarding design experience.

"Some background information may help to put Mercer's design sequence in perspective. The School of Engineering has a student enrollment of approximately 400 students. The school currently offers a Bachelor of Science in Engineering degree with the students majoring in biomedical, electrical and computer, environmental, industrial, or mechanical engineering. The school also has a technical communication department offering a Bachelor of Science degree in Technical Communication' [,2]. The engineering students share a large engineering core curriculum, part of which is the senior design sequence and part of which is a rigorous technical communication course offered in their junior year. Mercer is also somewhat unique in that the students have a three quarter freshman engineering sequence of which the last quarter is a group design project.

The senior design course sequence is broken into two quarters (each course is three quarter hours of credit). The preliminary design is completed in the first quarter. The second quarter is the build, test, and redesign portion of the project. A written document is submitted and an oral presentation is made to fellow students and to all interested school of engineering faculty at the end of each term. A user's manual is also submitted by the teams at the end of the second quarter. Multidisciplinary proj ects and multidisciplinary teams are strongly encouraged, making Mercer one of about21 % of the engineering programs allowing their students to work on interdisciplinary proj ects[3]. The group sizes range from a single student to five students. However, we have found that a group of three is usually the best size for helping the students learn about team-building issues. Projects are sponsored by industry, a National Science Foundation grant to aid the disabled, various departments within the school, or by faculty members. In each case there is a client, a team manager, and one or more technical advisors. As course co-directors, we serve as the team managers. Between us, we have a wide technical background which is useful for coaching interdisciplinary teams and projects. The technical advisors are generally engineering faculty but are sometimes engineers or managers from industry. Their role is to provide specific expertise related to the projects, advise the students, and to check the technical correctness of the engineering analysis performed by the students.

All projects are open-ended in nature and most have been very ambitious. Example projects include the design of a large low-speed, open-circuit wind tunnel with a 1 'x 1 'x2' (w x h x 1) test section; a wheelchair lift for disabled elementary students to access an auditorium stage; solar car components and systems used in Mercer's entry into Sunrayce ' 93 and '95; a special tool for the removal and installation of Taper-Lok fasteners in the wing of the F-15 aircraft; an operational amplifier (741 and 324) chip tester; a device to control the flow of coal from the coal reclaim hopper at Georgia Power's Plant Arkwright; a computerized Attribute Data Management System at Pratt& Whitney Aircraft Georgia facility; and a tool, die, and the associated process to produce a door assembly part for Blue Bird Bus Co.

II. Helping Students to Meet the Challenges

To help students bridge the gap between engineering science and engineering design, faculty advisors need to take on the role of coaches; that is they need to show how good fundamentals of engineering science and design methodology are applied in the context of a specific problem. We will now discuss elements of our approach to providing our students with the much needed "coaching."

<u>Weekly Meeting</u>

The most effective method of managing the teams to ensure a successful design experience is to hold frequent (weekly) meetings between the course co-directors and the student teams. A three-hour time block is set aside each week for this. The first 45 minutes are used to present a topic such as proposal preparation, brainstorming, etc. Individual 20 minute meetings are then held with each team. We ask each team to compare their progress to that indicated by their Gantt charts. We help them overcome any road blocks to progress. Finally, we ask them to specify their goals for the next week again referring to the Gantt chart. The rest of the 3-hour time block is available for the teams to work amongst themselves.

<u>Proiect Notebooks</u>

We have found that having the teams maintain a project notebook helps them manage the large amount of documentation and time that is associated with these projects. The following items are required to be in the notebook: the performance objectives or specifications as detailed by the clients; the proposal; the results of all literature, Internet, and background searches; the results of brainstorming sessions; a log of the time spent on the project; detailed Gantt charts; conceptual and working drawings (which would include schematics for electrical circuits, flow charts for software type projects, and flow diagrams for process improvement types of industrial engineering projects); the engineering analysis supporting the design choices; all feasibility and merit analysis results; design documentation from the first quarter; budget information; and parts list. Each week we review the progress notebooks in the meetings with the student teams to help them effectively manage their time and progress. If sufficient progress has not been made, it will be apparent as we review the dated material (or lack thereof) in these notebooks.

<u>Decision Analysis</u>

A common mistake often made by inexperienced design engineers is to latch onto the first idea that might work, thereby ending the consideration of alternative solutions. To counter this seemingly reflexive reaction in the hopes of arriving at a more optimal solution, classic engineering design methodology calls for the development of a number of alternatives through the "brainstorming" process. Next, "feasibility criteria" are applied to eliminate impractical alternatives from further consideration. Once this is accomplished, a system of weighing the tradeoffs inherent in the remaining alternatives (e.g., cost versus performance or strength versus weight) is needed. This calls for a listing and prioritizing of desirable aspects or "merit criteria" which will most likely be both qualitative and quantitative.

Quantifying something that is qualitative in nature is always difficult, but it is especially uncomfortable for students who lack experience with ambiguous situations. We try to reassure the students that such ambiguity is part and parcel of most design challenges. The bigger challenge, though, is often getting the student to arrive at a score for quantitative merit criteria using the performance predictions made " possible by appropriate engineering analysis. Faculty who have taught design methodology to freshman or sophomores know that scores are often numbers between 1 and 10 that are simply "pulled from the air. " By the time students are seniors, they have the engineering science background that enables them to arrive at well-supported scores for use in decision analysis. Faculty "coaches" can help the students make the connection between the predictive power of engineering analysis to the careful and systematic evaluation of alternatives in the design process.

Vendor Catalogs and Support

Students who have not worked in industry as summer-hires or as co-ops are often unaware of the universe of equipment, supplies, and materials beyond the local building supply or electronics store. We provide an introduction to all that is available by maintaining a library of vendor catalogs (e.g., Omega, Thomas Registers, Edmund Scientific Company, Grainger, Davis Instruments, Cole Palmer, Digi-Key, Jameco, Newark). Additionally, we pass along tips on making effective use of the vendors' technical support staff. For example, it is important for the students to communicate to the vendor that they are serious customers with a purchase order.

Technical Communications

In the past, it is has been alleged that engineers as a group have generally lacked good communication skills. To address this perceived shortcoming and to better prepare our graduates for professional practice, good technical communication skills are reviewed and stressed throughout the course. The form of the written documentation is described as well as the format for the oral presentation. The written documentation must be turned in by the teams 72 hours before their oral presentation. This gives us sufficient time to review the material and prepare questions for the oral presentation. It also forces the teams to finish the documentation in time to prepare for the oral presentation. The students are required to give a "dry run" of their oral presentation at least one day before the presentation is scheduled. This presentation is not graded but only serves to help them organize and work out some of the details of the presentation.

Feedback Mechanisms

The senior design sequence provides an opportunity to demonstrate that open, two-way communication increases the likelihood of continuous process or product improvement. Students are asked several times during the quarter to write down their concerns (anonymously) about "the way things are going" in the course. This gives the course directors the opportunity to better explain or justify why important although perhaps unpopular requirements are imposed on students. Just as frequently, however, the students raise a concern about something that can be improved. This practice has helped to fine-tune our course.

Faculty members who act as technical advisors are also asked to comment about how effectively the student teams made use of their availability. Students are encouraged to take the initiative in all meetings with the technical advisor and to set the agenda for short but frequent (at least weekly) meetings. It is also important for students to give the technical advisor time to make comments on their engineering analysis so that the appropriate corrections can be made.

At the end of the quarter, the entire faculty is invited to attend the oral presentations and to make comments on the quality of the design work and the quality of the presentation. Obviously, this feedback is important for the students, but it also provides critical feedback to the faculty on how effective they have been in teaching all of the subjects which the students draw together in senior design. Finally, the students " are asked to comment on the relative contributions of each student team member. This practice has helped to reinforce proper team building activities that increase the likelihood that each person pulls his or her own weight.

III. Summary

The key to effectively teaching senior engineering design that requires the delivery of a working prototype is to assume the role of a coach or mentor. This can be accomplished through the following mechanisms: holding short but frequent meetings with the student teams, requiring the students to maintaining an organized project notebook, reinforcing the use of engineering science in developing the scores used in decision analysis, providing a library of vendor catalogs and information, emphasizing good technical communication through "dry runs" of presentations, encouraging student interaction with technical experts on the faculty and from within industry, and by asking for lots of feedback from all of the participants. The authors have found that these activities have helped to provide the seniors with a stimulating and enriching "capstone" design experience that helps them be ready to make contributions immediately after graduation.

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