Enhancing Communication Skills in Senior Design Capstone Projects

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I. Introduction

Most engineering faculty would acknowledge that engineering students do not enjoy writing while at the same time agree that writing skills are tremendously important to the practicing engineer. ABET Engineering Criteria 2000 includes demonstration of communication skills; feedback from industry employers indicates that this is even more important than technical skills\textsuperscript{1}. The senior capstone experience provides an excellent opportunity for polishing written and oral communication skills in a manner that is both palatable and successful for engineering students. We are taking advantage of this opportunity in our senior design sequence at the University of Cincinnati in the Electrical & Computer Engineering and Computer Science department. Historically, each senior project was supervised by a faculty member with appropriate technical expertise. All students shared common reporting requirements due at the end of each term. The quality between projects varied greatly and seniors expressed dissatisfaction with inconsistent levels of interaction and feedback from faculty advisors. In order to address both weaknesses, several curriculum modifications were initiated in the Electrical Engineering (EE) and Computer Engineering (CompE) senior capstone courses in Fall 1999. The improvements include a regular weekly class meeting guided by senior advisors (one EE and one CompE professor), emphasis on team projects, and systematic and incremental writing deadlines.

The Fall term is now devoted to the formation of teams and the writing of a complete design report. A rigorous schedule of due dates allows feedback on writing as well as content. The weekly writing assignments include requirements, specifications, multiple levels of design diagrams, a task/effort matrix, a task timeline, and a testing plan; additional writing assignments include a statement of how ABET concerns such as health, safety, ethics, social impact, and economics are addressed by the project, as well as a self-evaluation. In the self-evaluation, students reflect on how their mandatory co-op experience, as well as their course work, have prepared them to undertake the project. Project implementation and oral status reports take place in the Winter quarter. In the Spring term, testing, refinement, writing final evaluations, and presentation at a senior forum are done.

The important curriculum innovation is that the students usually do not write more than a page or two for any weekly assignment, yet when assembled the individual assignments form a complete
design report. Students appear to appreciate the incremental deadlines because they help to avoid procrastination; receipt of timely and detailed feedback addresses lack of faculty interaction. In the following sections, the quarter schedules and writing guidelines are described. Preliminary assessment results are discussed in the concluding section.

II. Fall Quarter

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Each item in the schedule is briefly described below.

1. professional biography: contains a student’s name, email address, and short bulleted lists for co-op or other professional experience and responsibilities, skills/expertise areas, and areas of interest/type of project sought. Professional biographies are posted on the department’s webpage to facilitate team formation for students with similar interests.

2. project description: focuses on what is to be accomplished, not how it will be accomplished. It contains a general description of the problem domain that is readable by an educated audience without requiring specific technical expertise, a description of the problem (and why current solutions, if any, are inadequate), the overall goal of the project (what will be accomplished by the final result at the project’s completion), a list of any relevant subgoals of the project, a list of known team members and their email addresses, and a list of background/skills/interests that are relevant to the project. Project topics are generated both by students and professors; the majority of projects are defined by students and are related to their co-op experiences. Project descriptions are also posted on the department’s website to facilitate team formation. Students solicit faculty advisors based on mutual interests.

3. requirements: includes a description of the project background, statement of work, uniqueness and impact, deliverables, and potential for technology transfer.

4. a. task list: gives one or two sentences about tasks to be completed; each task should have a deliverable or milestone associated with it.
   b. timeline: dates of all milestones and deliverables associated with each task.
   c. effort matrix: lists high/medium/low/none (or percentage) of effort for each task (vertical axis) and each person on the team (horizontal axis). Optionally, the timeline and effort
matrix can be combined.

5. system diagrams: level 0 shows the “black box” view of a system (high level inputs and outputs); level 1 divides level 0 into subsystems, and level 2 shows details of the subsystems.

6. technical specifications/standards: identifies for each task the relevant materials, tools, processes, practices, protocols, languages, or technologies and how they will be used.

7. statement of ABET concerns: each team chooses two of the following considerations and reflects on their impact on project design decisions: economic, environmental, ethical, health and safety, sustainability, social, political, and manufacturability.

8. self-assessment: outlines relevant coursework and co-op experience for each student’s tasks.

9. design report: contains all of the above documents formatted as a coherent, uniform report with section and page numbers and a table of contents.

Each student’s grade for the Fall term is determined by both the senior advisors (75%) and faculty advisors (25%).

III. Winter Quarter

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1. oral status reports: each project team gives a 10 minute presentation to the entire class that contains the following information: project name, team member names, faculty advisor name, motivation/background for the project, problem statement, tasks, timeline, completion status to date, and expected results or contributions of the project.

2. interface specifications: visualizes the end result of the project (what the user will see) in the form of line diagrams, screen layouts, dimensions for physical devices, etc.

3. test plan: describes how subcomponents will be checked for faults as well as how the entire system will be checked. Gives examples of both correct system inputs and examples of categories of bad inputs (boundary conditions, erroneous data, etc.) correlated with subsystems as given in system diagrams. Alternately, if the system relies on experimentation for its final design, description and results of experiments, as well as description of any other planned experiments to be conducted, can replace the test plan.

4. midterm status report: contains a problem statement, task list, timeline, and completion status as of the fifth week of the quarter.

5. design report: contains revisions to version 1 of the design report as well as additional
documentation generated in the Winter quarter.

Each student’s grade for the Winter term is determined by both the senior advisors (50%) and faculty advisors (50%). In addition, students are allowed to confidentially submit a multiplier (from 0.5 to 1.5) to the project grade that may increase/decrease the team project score for individuals who contribute more/less to the final outcome of the project. All the multipliers are averaged for a particular student and applied to the project grade to obtain an individual grade. The default multiplier value is 1. There are no class meetings after the 6th week of the quarter to allow students to focus on implementation.

IV. Spring Quarter

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1. updated status report: same format as Winter quarter midterm report, revised to reflect current status.
2. results of testing/experimentation and refinement: reiterates test plan or experimentation of the Winter quarter and gives results of conducting the test plan/experiments.
3. assessment of goals vs. achievements: describes to what degree each of the project’s goals have been met (or not, and why).
4. user manual: operational guide for the system or project (how to use it and examples of its use including sample input and output, known bugs and/or exceptions handled).
5. design report: final version of the design report incorporating revisions and new material from Spring quarter.
6. senior project forum: each team creates a trifold, freestanding, color poster describing their project’s goals, achievements, and impact. During a two-hour open forum, faculty and students are invited to view and discuss senior projects.
7. demonstration/presentation of projects: final grading of the projects by both faculty advisors and senior advisors includes a brief presentation by all team members and demonstration of working projects.

Each student’s grade for the spring term is determined by both the senior advisors (25%) and faculty advisors (75%), along with a multiplier supplied by teammates as in the Winter quarter. In practice, very few students supplied multipliers other than 1 for their team members. There are only two class meetings in the spring term, one initial class meeting and one prior to the senior
V. Preliminary Assessment

Two means for students to provide feedback in their senior year to the ECECS department are 1) a survey regarding their preparedness entering the senior year, and 2) a survey about their senior design project experience prior to graduation. Each survey has been given once and the results are described below.

In Spring 2000, EE and CompE seniors in the class of 2000 were asked 10 questions regarding their satisfaction with the senior design project and recommendations for improvements. 8 of 55 students responded (the survey was given in the final week of the term; it will be given earlier in Spring 2001). Several questions gave a numeric scale from 0 to 10 and n/a (not applicable) where 0=very negative, 5=OK, and 10=very positive. The questions and comments related to communication skills are summarized here:

1. “How do you feel about the structure and content of the Fall quarter?” The numeric rating had an average of 6 (a little better than “OK” in the given scale). Three of the lower-scored comments (scores of 4, 5, and 5) expressed dissatisfaction with too much time spent trying to match students to projects/teams. In the worst cases, this phase took about 4 weeks in Fall 1999, but has been reduced to 2 weeks by more aggressive scheduling in Fall 2000. Other negative comments (scores of 3, 6, 7) regarded the writing assignments (“too much busywork”) and the lack of a detailed schedule for the entire quarter, although the student who reported a score of 7 said that “the amount of treeware required was about the same as I am used to on projects of similar size at Intel. So in that respect it probably gave some people good experience for what they should expect in the industry” (where “treeware” refers to paper documents.) The most positive comment (scored a 10) stated that “the Fall quarter had a lot of very helpful structure that deterred procrastination.”

2. “How can the design report be improved?” 7 of 8 students reported satisfaction and suggested improvements/additions, and 1 reported that it “was far too lengthy. We seemed to spend more time on the design report than we did on the actual project.”

3. “How do you feel about the oral and written communication part of the course?” 7 students responded with an average value of 6.57. The lowest score was 1, and this student said that a formal presentation for each team project should be given at the end of the year rather than the senior design forum where all students exhibit their projects concurrently. If this score is treated as an outlier, the remaining scores have an average of 7.5. Three of the positive comments suggested lengthening the time for in-class oral presentations; this has been implemented in Winter 2001 by requiring a 10 minute oral status report from each team rather than just a 5 minute overview of the project topic as done in Winter 2000. Three responses suggested that no modifications to the written documentation are needed, and 2 suggested that less writing be done.

4. “How can we improve the senior design forum?” The senior forum received 7 positive comments ranging from “great idea” to minor or no suggested improvements. The minor
improvements include having more outside visitors, scheduling less time for the forum, and doing the grading of the projects separately. All of these improvements have been incorporated into the plan for Spring 2001; the forum will be reduced from 3 to 2 hours, a separate presentation for grading, evaluation, discussion and demonstration will be scheduled, and reviewers from local industry will be invited. The most negative comment suggested elimination of the forum entirely and replacing it with individual formal presentations.

5. Students were also allowed to add any other comments at the end of the survey. Two comments expressed satisfaction with the senior advisors guiding the class (“thanks for everything” and “did a phenomenal job with senior design this year. Kudos.”) One student gave an extremely positive response: “I think the senior design project is one of the best things about my stay at UC. It gave me a chance to use everything I had learned from my co-ops and school to develop a real product.”

Although the number of responses is small, it appears that the curriculum revisions to the senior project are accomplishing their goals. Most of the suggested improvements have been incorporated in the curriculum for the class of 2001, with the exception of reducing the writing requirements.

In order to assess student preparedness entering the senior year and determine if any shortcomings could be addressed in the senior design project course, 39 EE and CompE seniors in the class of 2001 were surveyed in Fall 2000 based on Criterion 3 outcomes in ABET Engineering Criteria 2000. In order to determine strengths and weaknesses in the outcome areas, students were asked how they would rate their knowledge and skill level for each outcome on a scale of 5=very strong, 4=strong, 3=about average, 2=weak, and 1=very weak for achievement of the outcome, and 4=very important, 3=important, 2=somewhat important, 1=of little importance, and 0=none for how important each outcome was in their workplace experience. Students typically co-op for six 10-week periods (a minimum of 4 co-op quarters is required for graduation.) The results are plotted in the graph below for the outcomes summarized here.

- an ability to apply knowledge of mathematics and engineering skills.
- an ability to design and conduct experiments, as well as to analyze and interpret data.
- an ability to design a system, component or process to meet desired needs.
- an ability to function well on multi-disciplinary teams.
- an ability to identify, formulate, and solve engineering problems.
- an understanding of professional and ethical responsibility.
- an ability to communicate effectively.
- the broad education necessary to understand the impact of engineering solutions in a global and societal context.
- a recognition of the need for, and an ability to engage in lifelong learning.
- a knowledge of contemporary issues.
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.
In the graph below, importance of each outcome is plotted against skill level for each. The average values for importance and skill are shown as dashed lines. Outcomes d, e, f, g, and k fall in the upper right quadrant, indicating that they are both important and students feel that they possess these skills (working on multidisciplinary teams, solving engineering problems, acting with professional responsibility, communicating effectively, and using techniques/skills/tools in engineering practice.) It is noteworthy that students give communication skills the highest importance and also feel that they have the highest competence in this area. The only outcome listed as important but with below average competency is c (ability to design a system/component/process to meet desired needs.) Assessment will be conducted in the Spring to determine whether the senior design project improves students’ competency in this outcome area, as well as to determine if the emphasis on written and oral communication with incremental deadlines enhances their already strong ability to communicate effectively.
Bibliography
2. Adapted from a University of Florida survey conducted by T. Davis: www.cise.uf.edu/~davis/Renewal.

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Karen C. Davis is an Associate Professor of Electrical & Computer Engineering and Computer Science and an Associate Department Head for Computer Engineering at the University of Cincinnati. In Spring 2000, she was awarded the College of Engineering’s Wandamacher Teaching Award for Young Faculty, the ECECS Department’s Restemeyer Teaching Award, and Engineering Tribunal’s Professor of the Quarter Award. She is a Senior member of IEEE and an ABET Computer Engineering program evaluator. Dr. Davis received a B.S. degree in Computer Science from Loyola University, New Orleans in 1985 and an M.S. and Ph.D. in Computer Science from the University of Louisiana, Lafayette in 1987 and 1990, respectively.