Assessment Opportunities in a Capstone Design Course

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Abstract

This paper describes activities related to ABET EAC assessment that have been implemented within a senior design capstone course sequence. The activities and instruments address Criterion 3, Program Outcomes and Assessment, and Criterion 4, Professional Component (specifically the major design experience). A variety of assessment techniques are used to obtain both quantitative measurements and qualitative indicators that can be used to demonstrate achievement of outcomes as well as to improve the course itself and the program curriculum as a whole. The techniques include

- an initial survey of achievement vs. importance of all outcomes,
- an individual self-assessment assignment,
- a project-specific statement of ABET concerns (health, safety, environmental, ethical, etc.),
- student assessment of team functioning,
- peer assessment for design reviews,
- an assignment to discuss current events related to professionalism and ABET concerns,
- a small group assessment (over the entire program curriculum),
- an exit survey for achievement of all outcomes, and
- peer assessment of project final presentations.

Examples of assessment instruments, results, observations, and discussion are given. A timeline illustrates how these activities are integrated into a design lifecycle and coordinated with design project deliverables.

1. Introduction

Electrical and Computer Engineering seniors at the University of Cincinnati take a capstone design course sequence that extends across the entire senior year[1]. Students typically self-organize into teams of 2-4 people and select project topics proposed by an ECECS faculty member; alternately, students propose projects based on their co-op experience or personal interest. In either case, students have a technical project advisor as well as a professor who supervises the course work of all teams. The course work itself can be generalized to most engineering degree programs while the technical content will vary with the project and engineering discipline. The focus of this paper is how

ABET assessment can be conducted within the framework of a capstone design course, rather than on specific project topics themselves.

The University of Cincinnati employs a quarter system and thus the senior capstone course sequence for ECE seniors is divided into a fall, winter, and spring term, covering about 33 weeks. The techniques described here could be adapted in a straightforward manner to a semester system by splitting the winter term assignments. The class meets once a week for 2 hours, and assignments are due on non-class days to increase turnaround time on grading and returning them. The fall term is devoted to the formation of teams and the writing of a complete design report via weekly incremental writing assignments. Peer-assessed design reviews, project implementation and current events assignments take place in the winter quarter, and the writing assignments for project documentation are due every other week. In the spring term, testing, refinement, writing final self-assessments, and a peer-assessed presentation and demonstration are done.

An overview of selected assessment activities conducted in each academic term is given below. The activities are further elaborated in the subsequent sections, and a table in the last section summarizes the instruments and which criteria they address.

Fall activities include

- an initial survey of achievement vs. importance of all outcomes,
- an individual self-assessment assignment,
- a project-specific statement of ABET concerns (health, safety, environmental, ethical, etc.),
- a team and individual responsibilities contract, and
- student assessment of team functioning (also done in winter and spring).

Winter activities include

- peer assessment for design reviews, and
- an assignment to discuss current events related to professionalism and ABET concerns.

Spring activities include

- a small group assessment (over the entire program curriculum),
- an exit survey for achievement of all outcomes, and
- peer assessment of project final presentation.

2. Criterion 3: Outcomes (a-k)

One mechanism to measure achievement of all outcomes for all students is to survey the students themselves. While a recent ABET EAC white paper indicates that self-reported data alone is insufficient to demonstrate achievement of outcomes[2], surveys do provide useful snapshots of student perceptions that can be further investigated and supported by additional assessment mechanisms described in later sections of this paper.

We administer two outcomes surveys to seniors each year. A pre-survey is given in the fall that addresses both achievement and importance of all Criterion 3 Outcomes (a-k). A post-survey is given in the spring that addresses achievement only. The fall survey is administered by the ECECS department to seniors in their senior design course. It asks the students to rate their skill or achievement level on a scale of 5=very strong, 4=strong, 3=average, 2=weak, and 1=very weak for each outcome, worded exactly as in Criterion 3. In addition, the students are asked to rate the importance of the outcome. The spring survey is administered by the College of Engineering (CoE) to all graduating seniors in engineering degree programs, and it uses a scale of 5=yes, definitely (excellent), 4=above average (good), 3=average, 2=poor, 1=no, not at all. The spring survey asks questions that reword the outcomes. The question corresponding to outcome 3(i), lifelong learning, for example, asks directly about plans to pursue formal study. "An appreciation for, and ability to engage in, lifelong learning" may involve less formal and equally valid channels.

2.1 Self-reported Achievement and Importance Data

There are several ways to analyze the data collected in the pre- and post-surveys administered to seniors in the fall and spring terms, respectively. Our approach to analysis is summarized in Table 1.

Table 1. Analyzing Outcomes Surveys

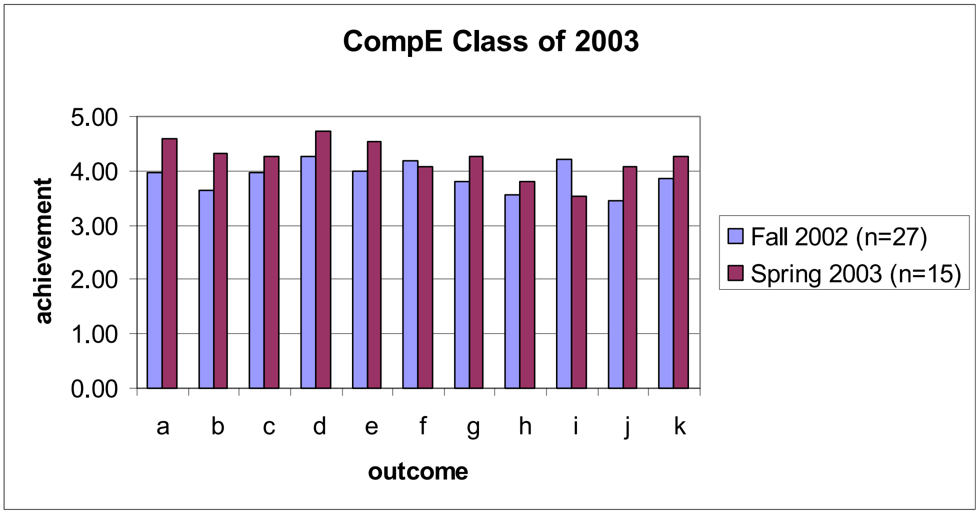
approach	*investigates*
1. comparison of pre- and post- achievement levels each year	effect of senior year experience
2. average achievement levels in post-surveys across all years	outcome achievement levels at program completion
3. paired differences in achievement for post-surveys in alternating years	areas with increased/decreased improvement in senior year
4. importance vs. outcomes scatterplots for each year	emphasis and achievement levels entering the senior year
5. average achievement in pre-surveys across all years	program strengths, areas of emphasis prior to senior year
6. paired differences in achievement for pre-surveys in alternating years	areas with increased/decreased improvement in program prior to senior year

Selected summary results, observations, and discussion are offered below for approaches 1, 3, and 4.

2.1.1. Comparison of Pre- and Post-surveys on Outcome Achievement for Class of 2003

Average values for achievement of outcomes in the fall pre-survey and spring post-survey for the Computer Engineering class of 2003 are summarized in the graph given in Figure 1. The labels on the horizontal axis correspond to Criterion 3 (a-k) outcomes.

Figure 1. Pre- and Post-survey Results for Seniors



The results indicate that all outcomes with the exception of (f) and (i) show positive increases in achievement levels. The sample size for the spring survey is smaller (slightly more than half) than that of the fall survey. The two questions from the CoE exit survey that show decreases for outcome achievement are discussed here.

Outcome (f): "Do you have an understanding of professional and ethical responsibility?"

Both of these topics can be addressed in more detail in the senior design course. In 2003-04, the course was moved to a classroom with desks rather than an auditorium-style classroom to facilitate group discussions and in-class exercises. Additional topics for active learning in the class this year include professional and ethical responsibility as well as some team-building and monitoring exercises.

Outcome (i) "Do you plan to continue to improve your engineering skills through graduate studies or professional level education?"

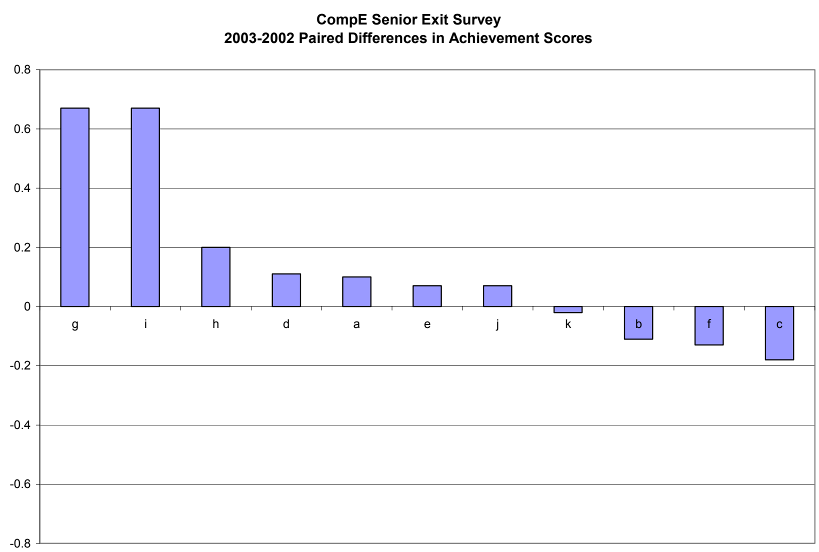
As discussed above, it is possible that students interpreted this question in the sense of formal education (graduate school, law school, etc.) rather than in a more casual sense of an appreciation for professional growth and learning. Other instruments to measure this outcome are self-assessments in the final senior design reports, as well as in the peer evaluations conducted during the final presentation and demonstration of each project. Both of these assessments are described in another section of this paper.

The comparison of results from the ECECS departmental instrument to a CoE instrument over all outcomes indicates that computer engineering seniors enter the senior year with adequate achievement levels in all outcome areas and improve in almost all areas over the course of the year.

2.1.2. Post-survey Achievement Comparison for the Classes of 2002 and 2003

Figure 2 shows an ordered ranking of increases to decreases in outcomes achievement reported by the Computer Engineering classes of 2003 and 2002 on the CoE senior exit survey.

Figure 2. Exit Survey Results



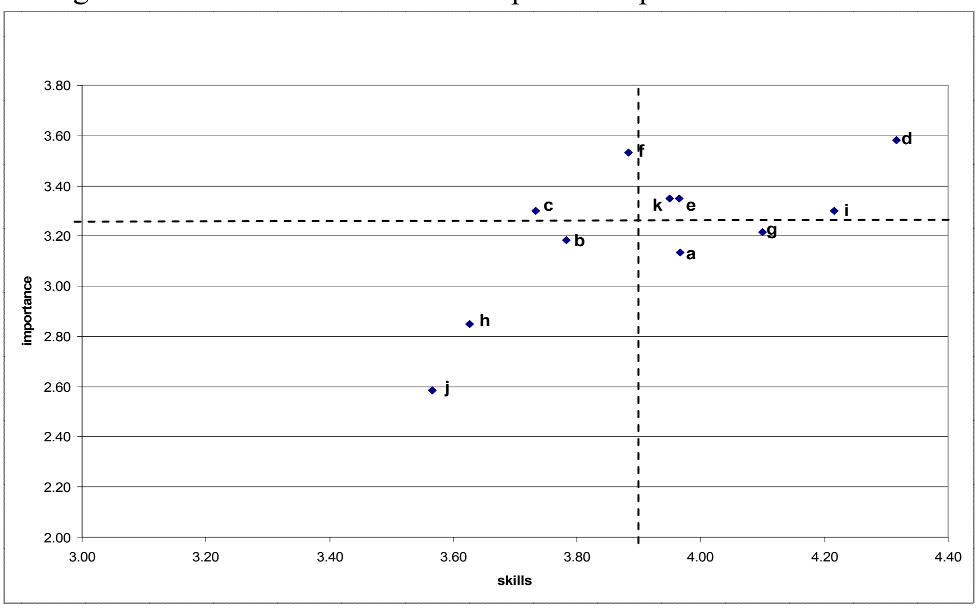
Significant increases in outcomes (g) communication skills and (i) lifelong learning are evident between the classes of 2003 and 2002. The remaining differences in outcomes are not as significant. Several new writing assignments were added to the senior design project course in 2003, including one that required students to write essays about current news events related to their discipline and to the ABET capstone concerns (environmental, health and safety, ethical, etc.) Additional oral reports were added to the class, including a design review in the winter quarter. The design reviews and the final project presentation in the spring were both peer-assessed as well.

Outcome achievements continue to be rated above "average" (not statistical average) by seniors at the time of program completion. Modifications to the senior design class appear to be having an impact on communication skills and appreciation for lifelong learning.

2.1.3. Importance vs. Outcomes Scatterplots

The scatterplot given in Figures 3 plots the average scores for importance of an outcome on the y-axis and achievement (skill) for the outcome on the x-axis. The average values for importance and skill are shown as dashed lines. Since the surveys are administered in the ECE senior design project course and reported to the class as a whole, the results are not separated by program. Further, other assessment instruments are conducted for teams and projects which may contain students from both majors; thus it makes sense to keep the data combined here so that it captures the same subjects as other instruments given to seniors in their senior design class.

Figure 3. ECE Class of 2003 Scatterplot of Importance vs. Outcomes



For the class of 2003, outcomes (d), (e), (i), 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, possessing an appreciation for lifelong learning, and using techniques/skills/tools in engineering practice.) The outcomes listed as important but with below average competency are (c) ability to design a system/component/process to meet desired needs, and (f) understanding of professional and ethical responsibility.

Over two recent graduating classes[3], our students consistently respond that outcomes (d) working on multidisciplinary teams, (e) solving engineering problems, and (k) using techniques, skills, and tools in engineering practice, are important and they have highest achievement in these outcomes. The only outcome consistently listed as important but with below average competency is (c) ability to design a system/component/process to meet desired needs. Additional assessment is needed throughout the senior year in order to determine whether students improve in competency in this area. The capstone design course provides opportunities for self assessment, peer assessment, and faculty assessment of outcomes achievement. These results are reported in other sections of this paper.

The areas that are consistently reported as below average in both importance and achievement are (b) design and conduct experiments, (h) broad education for global/societal context, and (j) contemporary issues. Students do indicate increased achievement in these areas in the exit survey (class of 2003), and the initial achievement scores are still in the self-reported category of "average" (not statistical average.) In the next section, the outcomes are discussed with respect to program curriculum and feedback from two constituencies, alumni and industrial advisors.

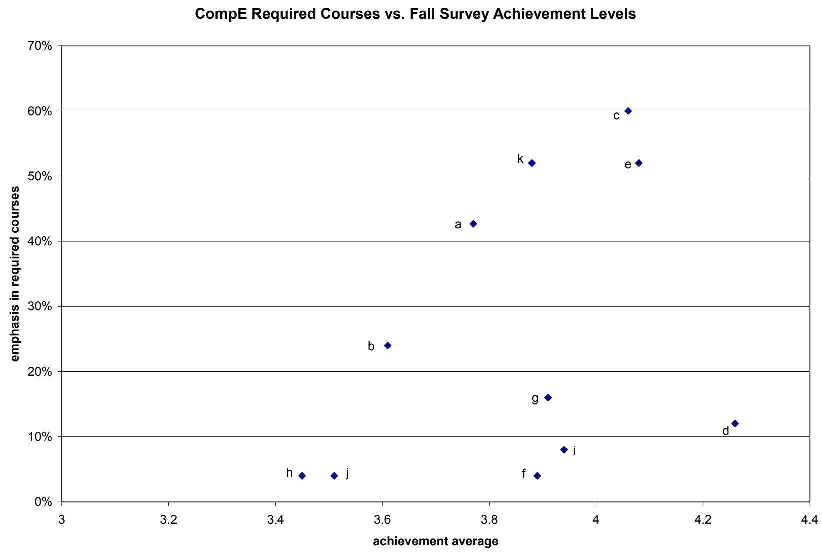
2.2 Relationship to Program Curricula and Constituency Input

In order to determine the relationship between program curricula and achievement of outcomes, we first examine the outcomes assessed in each undergraduate course. Faculty coordinators and teams have identified outcomes that are assessed in their courses. Every term the course is taught, each professor teaching the course is asked to assess to what degree the outcome is treated in the course. A rating of "high," "medium" or "low" indicates that the outcome is assessed for all students at that level; "some" indicates that some students (but not necessarily all) are assessed for that outcome; "none" indicates that the outcome was indicated for the course but not assessed or addressed in the particular offering of the course.

As an example, consider the Computer Engineering program curriculum. Approximately 60% of the Computer Engineering required courses have "high" or "medium" treatment of outcome (c), whereas only 8% of the required courses have "high" or "medium" treatment of outcome (h). The emphasis of each outcome is summarized in Figure 4 along the vertical axis.

In order to gain an understanding of how the emphasis of outcomes in courses is related to student perceptions of their achievement levels, self-reported achievement levels for the class of 2003 entering their senior year are plotted along the horizontal axis in Figure 4. Most of the outcomes are in a linear relationship that shows lower emphasis correlated with lower achievement (likewise for higher). The outcomes that are not linearly correlated with the others are (d), (f), (i), and (g). These outcomes have high achievement levels but low emphasis in the required course work part of the curriculum. These outcomes may have higher achievement levels due to co-op experiences rather than course work; we examine this in terms of employer evaluations and student self-evaluations administered by the Division of Professional Practice for each student and each co-op term, but do not present those results in this paper.

Figure 4. Relationship of Required Courses to Average Achievement Levels



In the process of discussing program educational objectives with two of our constituencies, alumni and industrial advisors, we collected some feedback about the relative importance of the Criterion 3 outcomes. Interestingly, the outcomes given lowest importance, (b), (h), and (j) by seniors (2001 and 2003) and have the lowest emphasis in our required course work, are ranked 8th, 14th, and 13th by our Industrial Advisory Board (IAB), respectively. The alumni feedback (5 years after graduation) has the same top outcomes (d), (g), and (e), as the IAB feedback. These are not only consistently important to our seniors, but they are also outcomes with high (self-reported) achievement scores.

3. Criterion 4: Capstone Design Experience

We address the portion of the professional component criterion that focuses on senior design in this paper:

> *Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political.*[4]

3.1 Knowledge and Skills from Prior Program Experience

Students write a short essay that addresses how their co-op experiences and previous course work have prepared them to undertake their senior design project. The assignment is loosely specified (2 paragraphs, 6 sentence minimum addressing the impact of co-op and course work), thus allowing for greater freedom of expression and creativity than a structured survey. As a result, students give highly individualized and candid answers, but do not necessarily address all outcomes that would be of interest to us. However, it gives students the opportunity to reflect on the course work and co-op knowledge and skills that have brought them to the point where they are now ready to initiate and complete a significant design project. This addresses the Criterion 4 mandate that the capstone experience should be the culmination of previously acquired knowledge and skills.

Nearly all students mention that their course work and laboratories are valuable and contribute to their ability to reinforce and extend their hands-on skills during co-op. Some examples from initial self-assessment essays include the following.

> *Undertaking and completing a senior design project is going to involve bringing lots of skills from different areas together. These include theoretical concepts, teamwork, and the ability to learn new things quickly and apply them. ... I have been exposed to all of the traditional electrical engineering topics including electronics, math, signals and systems, and programming. ... Most importantly is that through the coursework that I have had, I have learned how to learn better, so I will be able to work well with the new ideas that will be involved in a design project. Brian Marks, EE 2003*

> *Co-op has also exposed me to applications of the theory I have been learning in my course work. It showed me how theory relates to the real world and what to focus on when learning the theory. Through my co-op experience, I have refined my problem solving techniques through further experience. Andy Gilmore, CompE 2003*

> *My co-op assignment was at GE Aircraft Engines ... I worked on various components such as thermocouple probes, pyrometers, and resistance temperature detectors. ... Additionally, on all of the engines, engine to aircraft communication is handled via digital buses. Therefore, much of my time was spent with understanding different bus protocols and working through communication problems between computers, particularly in the test rigs. While none of this communication was wireless, the experience will be of particular use to me on this senior project because the project involves digital data transfer. Frank Wilson, EE 2003*

The project I will be working on is a wireless RS-232 device. Useful course work that I have already completed includes Signals and Systems, Network Analysis, Electromagnetic Fields, and Electronics. Signals and Systems will help because we will need to process signals from the digital realm, into the analog realm, and back for the wireless transmission. … This year I am taking Microwave Communications, Communications Systems, and Digital Communications. All these classes provide a more specific background that is directly application to our project. Adam Swejk, EE 2003

Others report on developing and honing an appreciation for lifelong learning. Examples from initial and final self-assessments are included here.

Having worked in a research and development group as part of my co-op experience has given me the proper skills to be able to adequately research information for a given project. … I was required to quickly learn new skills in order to complete certain tasks. This ability to rapidly adapt will ultimately aid in the completion of my project. Andrew Cole, EE 2003

A large portion of the filtration work required reading numerous papers and journals discussing the benefits of different stereographic filtration techniques. … Many hours were also required researching image acquisition hardware and how to use it. Regardless, I realized that I typically enjoy the sleuth work that goes into finding hardware and software or other new development tools. Jeremiah Flerchinger, EE 2003

The final assessments uniformly address lessons learned about Criterion 3(c) developing a system, component or process. Illustrative examples include the following.

Over the course of this senior project, I learned that it is very important to maintain a timeline with quantifiable deliverables. This insures that progress is continually made and that work does not fall behind. I also learned how to spec out an electronic system in hierarchical blocks and then to revise those into lower and lower level designs similar to the design of software systems that I am accustomed to from co-op experience. Ted Carraher, CompE 2003

Starting with the design of the application, I've learned how important writing such documents as the requirements document can be. Throughout the entire implementation of the application, I repeatedly referenced the requirements document for any questions that arose. Putting ideas on paper before any development work is definitely easier than designing while implementing … Chad Glaser, CompE 2003

Another thing I learned from my project was how to work with contractors, engineers, and technicians. I had to convince some engineers who had several years of experience to make changes on a production line and that by making those changes the line would work better. Naghmeh Tefagh, EE 2003

3.2 Realistic Constraints in Design

An essay given in the fall quarter has each project pick two (three in 2003) of the most relevant constraints and discuss how they impact the project's design. The version of the assignment given in 2002 is shown in Figure 5. At the beginning of their projects, students are not as aware of what will constrain their project as they are during later stages of the design process. In an attempt to provide some guidance for the students, questions about each of the concerns are provided; these are not intended to be definitional and are subject to further revision or interpretation by the students as dictated by particular projects. A follow-up assignment could be given in the spring that requires the students to address additional concerns that surfaced during their project's design and development.

Since not all projects encompass all constraints, the students select the most pertinent ones for their particular project. Table 2 gives a breakdown of which constraints were addressed by the projects done by the classes of 2003 (25 projects, at least two constraints) and 2004 (19 projects, at least two constraints plus economic constraints). A future modification to this assignment would be to require that all projects address sustainability and manufacturability since they appear to be widely relevant.

In order to reinforce the ABET realistic constraints as professional concerns, students are assigned a current events assignment in the winter term that requires the following activities:

1. Find an article, either a quality newspaper article or a popular technical press article (IEEE Spectrum, IEEE Computer, or Communications of the ACM, for example) that relates one aspect of the 8 ABET concerns to your discipline or professional experience. Most quality newspapers are online, and you can also use the NEXIS software in the library to do keyword searches over newspaper articles.

2. Write an essay about it that consists of two paragraphs, 6 sentences minimum (each). The first should outline the main idea of the article and relate it to the ABET concern or concerns you've identified in it. The second should describe some aspect of the article (doesn't have to be the main idea, it could be just a sentence or comment in the article) that impacts your life, particularly your professional life, in some way.

Repeat this four times and cover at least 4 of the concerns. Turn in both a hardcopy of the essay and the original article.

This assignment emphasizes lifelong learning, professionalism, and written communication skills in addition to reinforcing the concepts identified in the professional component criterion as realistic constraints. The use of engineering standards mentioned in Criterion 4 is addressed by another assignment that is not discussed here.

Figure 5. Realistic Constraints Assignment

Statement of ABET Concerns **Fall 2002**

One interpretation of these is that they are constraints that come to bear on the solution that you are developing. Other interpretations of the items are possible (you don't have to limit yourself to this interpretation if you have another reasonable way to define the terms and state their relevance to your project.)

Here is one possible way that you might interpret the following items. This is meant to serve as a guideline or a way of thinking about the issues; use it or ignore it in favor of some other interpretation that you have devised ... whatever helps you the most.

The Constraint View

Each item below is viewed as a factor that influences the solution that you are designing. You have already developed functional requirements (how the system, device, etc.) should behave or what capabilities it should have. These are additional concerns that further define or restrict the possible solution space.

The main question to keep in mind is this: Does this factor impact the kinds of solutions that are viable for your project (and if so, how)?

1. *Economic*: are there financial limitations to the solution? For example, are you relying on freeware or shareware, or do you have a budget for actual purchases? Are your funds supplied personally or by a company? Are you restricted to UC or other facilities?

2. *Environmental*: are there limitations about where the project will be used or deployed?

3. *Ethical*: does your project have a direct or indirect impact on someone's quality of life? If so, what concerns or precautions are being considered to insure that this impact is positive (or neutral) and not negative?

4. *Health and Safety*: are there limitations either for the developers or users of the project?

5. *Sustainability*: for projects that have a lifetime beyond your senior year, what are the plans for continued usage and maintenance of the project? How are you building this into the design process?

6. *Social*: will your project be used for public service? Will it be used by a non-profit agency?

7. *Political*: will your project be used by government or military users? Are there constraints that arise as a result of this? (it must meet government or military specifications for documentation or robustness, for example.)

8. *Manufacturability*: is your project a prototype or an actual implementation that is intended for manufacture (duplication and distribution?) Even if the project will not be manufactured, is design-for-manufacturability a key goal?

Your Paper

In your paragraph about the concern you select (one paragraph per concern, choose two to discuss), you should explain how you are interpreting the item and then how it is relevant to your project. There should be one paper submitted per project.

Table 2. Realistic Constraints for ECE Senior Design Projects

constraint	*2003*	*2004*
economic	13	19
environmental	5	3
sustainability	15	10
manufacturability	11	12
ethical	5	3
health and safety	4	5
social	7	3
political	1	2

4. Peer Assessment for Selected Criterion 3 Outcomes

Students have two opportunities for conducting peer evaluations of other students' projects. The first occurs in the winter quarter in the form of a design review and the second occurs in the spring quarter as an assessment of the final presentation and demonstration.

4.1 Design Review

Design review documents prepared by each team are distributed to the reviewers prior to the scheduled oral presentation. The document should not exceed 10 pages and includes the following:

1. the project title, team members, and advisor,
2. a one or two sentence description of the goals of the project (what will be accomplished when it's completed),
3. design specifications (e.g., circuit diagrams) preferably at the highest level but including the detail needed to develop or implement the project,
4. a week-by-week timeline plus milestones for the rest of the project,
5. anything else that is pertinent to understanding the design,
6. results to date, and
7. how well the progress satisfies the requirements.

The reviewers complete the review form shown in Figure 6. The reviews are condensed into a single feedback summary returned to the project team. An example is given in Figure 7 for a project that mapped a region using communicating robots. Each project team is responsible for responding to action items in writing by the end of the winter term. This assignment addresses Criterion 3(c) and (g) since students conduct critical reviews of designs as well as prepare for their own design review and respond to critical commentary.

Figure 6. Design Reviewer's Assignment

Senior Design Project **Winter 2003**

Design Review Checksheet for Reviewers

Your team members' names: ____

Reviewed project name: ____

Preparation

Did you receive the documentation by noon on Monday of this week? yes no

Did you review the documentation prior to class? yes no

Evaluation

Does the design satisfy the project goals?

Are the specifications sufficient to implement the project?

Are there any unanswered questions or issues that need to be addressed?

Feasibility

Is the given timetable reasonable for completing the project?

Overall Assessment

difficulty of project:
easy average somewhat challenging very challenging

progress of project to date:
slow adequate (on track to complete) excellent progress

Action Items

What action items do you suggest for the project?

Figure 7. Sample Design Review Summary

Design Review Summary **Winter 2003**

project name: Cooperative LEGO Robots
number of reviews: 9
difficulty (1=easy, 2=average, 3=somewhat challenging, 4=very challenging): 3.2
progress (1=slow, 2=adequate, 3=excellent): 2.1

suggested action items:
- address the mechanical side in more detail in your next presentation.
- how will the robots know the entire room has been searched?
- why is it not appropriate to just tell a robot to go to a region and come back?
- are you using any kind of learning algorithm in the robots' programming?
- where is the design for what is communicated and how between robots?
- how do they find their way back?
- how is map data merged?
- the path integration will require very accurate information on wheel rotation. Exploring alternatives to path integration may be something to look at.

4.2 Presentation and Demonstration Review

Each senior project team is required to give a presentation and demonstration of their completed project. In the spring of 2003, there were 28 projects completed by 27 CompE seniors and 30 EE seniors. Each student was required to attend at least 5 presentations and complete the evaluation form shown in Figure 8. Since many students attended more than 5 presentations, there were 367 evaluations conducted.

The first set of questions rated presentation and project quality on a scale with 10=excellent, 9=very good, 8=good, 7=average, 6=fair, 5=poor, and n/a (not applicable). The composite score from this portion of the form was used in determining the project's final grade. The average values across all projects are summarized in Table 3. The categories map to outcome (c) design system, component, process, (g_1) oral communication, and (g_2) written communication.

The second set of questions addresses senior project course outcomes that were not directly addressed by the presentation and project quality evaluation. The students were asked to rate how well the student's or team's ability was demonstrated in the project. These scores were rated on the same scale used for determining the level of treatment of the outcomes in a course (as rated by the professor on the faculty-course feedback form). The scale used is 5=high, 4=medium, 3=low, 2=some, 1=none, and 0=n/a. The results are given in Table 4. Note that we split Criterion 3(a) into 3 parts, and only a_2 is addressed in the senior design course for all students.

Table 3. Design and Communication Scores

category	*outcome*	*average*
project overview	c	9.17
design process and results	c	9.00
testing/evaluation	c	8.79
project management	c	8.93
accomplishment of goals	c	8.90
presentation quality (verbal)	g_1	9.03
presentation quality (visual)	g_2	9.11

Seniors in the class of 2003 rated their peers from good to very good on aspects related to being able to (c) design a project and conduct its implementation; seniors rated their peers very good on (g) communication skills; all other outcomes were in the range of medium to high for achievement level.

Figure 8. Peer Assessment Form for Final Project Presentation

Electrical and Computer Engineering Senior Design Project
Final Presentation and Demo Evaluation Form

Project Title: ______________________________

Presenter: ____________________ Date: __________

evaluator's name (print clearly): ______________________________

	excellent	very good	good	average	fair	poor	
Project Overview description of topic, specific project goals and scope of the project	10	9	8	7	6	5	n/a
Design Process and Results system design diagrams, specifications, approach to solution	10	9	8	7	6	5	n/a
Testing/Evaluation approach used to test or evaluate the system, results of testing/evaluation	10	9	8	7	6	5	n/a
Project Management use of a task list, timeline, effort matrix (for teams), response to setbacks	10	9	8	7	6	5	n/a
Accomplishment of Goals project meets its stated goals effectively	10	9	8	7	6	5	n/a
Presentation Quality (verbal)	10	9	8	7	6	5	n/a
Presentation Quality (visual & length)	10	9	8	7	6	5	n/a
Team Member Participation	10	9	8	7	6	5	n/a

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Assessing Senior Design Project Course Outcomes (not used to grade the student or team)

The project demonstrates the student's or team's ability to:

	high	med	low	some	none	n/a
apply knowledge of science and engineering	5	4	3	2	1	0
design a system, component, or process to meet desired needs	5	4	3	2	1	0
function on multi-disciplinary teams	5	4	3	2	1	0
identity, formulate and solve problems in his/her/their discipline	5	4	3	2	1	0
understand professional and ethical responsibility	5	4	3	2	1	0
learn material/concepts beyond classroom or co-op experience	5	4	3	2	1	0
use techniques, skills, and tools of his/her/their discipline necessary for professional practice	5	4	3	2	1	0

Table 4. Course Outcomes Assessed

outcome	*description*	*average*
a_2	apply science, engineering	4.68
c	design system, component, process	4.64
d	function on teams	4.33
e	solve problems in discipline	4.61
f	professional, ethical responsibility	4.16
i	lifelong learning	4.62
k	techniques, skills, tools	4.71

5. Small Group Assessment

Historically, the department head has met with groups of students to hear concerns about the entire program curriculum prior to graduation. In Spring 2001, we initiated a small group assessment process with the entire senior class participating. An advantage of this process is that a short, ranked list of student concerns emerges from it rather than an unordered list where all concerns have the same significance. The process is outlined below, followed by the major discussion items raised by students and actions taken by the department to address student concerns. An overview of the process is as follows:

1. One minute to divide students into their respective degree programs (to be able to collect feedback on a program basis)
2. One minute to divide students into groups (no bigger than 5 per group)
3. One minute to assign roles with the group (facilitator to keep things moving, recorder/reporter to write ideas down and report them and a timekeeper to watch the clock)
4. 25 minutes to handout question sheets (one per group)
    - Focus on curriculum (classroom/lab learning)
    - 10 minutes to discuss best features (most beneficial to learning problem-solving and professional growth, etc.)
    - 15 minutes to discuss the features that need the most improvement
5. 30 or fewer minutes to report the results, approximately 5 minutes per group (the facilitator will record on chalkboard)
6. 10 minutes to have students make chalk marks next to the three most important issues
7. 5 minutes to allow facilitator to collect written sheets from groups and to record the totals on written sheets that appear on chalkboard

In Spring 2003, the areas for improvement that the students voted as most important by program are shown in Table 5, along with the ECECS Department's actions. The items receiving the most votes are listed here. Some students used all three of their votes for the same category.

Table 5. Comments and Responses

EE Senior Comments	*Departmental Actions*
1. Improve lab computers	Every computer replaced (Summer 2003)
2. Upgrade logic analyzers	Every logic analyzer replaced (Summer 2003)
3. Add soldering experience	ECES 151 and Measurements Lab now have soldering
CompE Senior Comments	
1. Improve lab computers	Every computer replaced (Summer 2003)
2. Improve VLSI minor	More specific comments and follow-up needed
3. Get rid of ENFD Heat Transfer	Replaced with a Network Systems Programming (454)

6. Teamwork Assessment

In order to begin having students think in terms of teamwork, we do two in-class exercises[5] that require discussion and cooperation amongst small groups. The first asks each group to identify characteristics of a team rather than a group, and then we put suggestions on the board for further discussion. The second exercise has the students identify negative experiences suffered as a result of bad teamwork. The suggestions are written on the board and then the students can offer practical suggestions for avoiding these experiences.

In Fall 2003, students identified the following characteristics for a team: has a focus, works constructively, agrees on objectives, has strategies, has accountability, can celebrate successes, has roles/responsibilities, has leadership, has longer duration, and "has a mascot." (In practice, mascots are optional.) They identified problems with bad teams as: may suffer from conflict, weak links, blame, arrogance, apathy, poor communication, and not meeting deadlines. To address both the positive and negative experiences of teams, each project team is then charged with writing their own team contract[5].

The team contract is started in class and revised and submitted two days later. The guidelines for the team contract are deliberately general, and no examples are given to avoid having students use them as templates. The students are required to list individual responsibilities to the team, team responsibilities, and penalties for non-compliance. Each team member signs the contract. The contracts are highly individualized and can be used to mediate disputes that arise during the year.

Team members evaluate themselves and their teammates at the end of the term (the form is given in Figure 9) and the scores are intended to be factored into the individual's course grade. The course grade computation is shown in Table 6. The weights used in Table 6 are for the fall term; the winter term uses .5 and .5, and the spring term uses .25 and .75, respectively, for course work grade and technical advisor grade. The advantage of doing this assessment is that it makes expectations for participation explicit, and allows for identification of serious problems and subsequent interventions if necessary. Our only experience using this assessment and grading formula found it not as useful as anticipated. Most teams rated their members and themselves fairly uniformly across all categories, so the individual score over team score was nearly always 100%. Other teams who rated a particular team member very low would have resulted in that person failing the course, and that seemed an inordinately heavy penalty when the students in question had done adequate work but missed a few meetings. Fine-tuning the formula and the assessment is a work in progress.

Another way to keep teams accountable and on task is to require that they meet at least once a week. Each team keeps a team notebook and records meeting notes that contain the date, start/end times, location, people present, issues discussed, possible resolutions, and action items. The team meeting notebook is submitted for review at midterm and end of term in the fall and end of term for both the winter and spring terms.

For more complete information about organizing and supervising teams, see the team workbook from Bucknell University's Project Catalyst[6]. This section merely illustrates some exercises and assignments that raise student awareness of team functioning, make them accountable for it, and allow it to be assessed.

Figure 9. Team Member Assessment Form

Peer Rating of Team Members Fall 2003

your name: ________________________________

In the assessment table below, place the number that corresponds to the descriptive phrase that most closely describes the person being rated. Evaluate each quality and each team member, including yourself, separately.

Rating Criteria

accuracy: the correctness of work duties being performed
- 1: made many errors
- 2: somewhat careless
- 3: average number of mistakes
- 4: accurate most of the time
- 5: exceptionally accurate

participation: availability for and participation in team activities
- 1: often absent or unavailable
- 2: lax in availability and participation
- 3: usually available and participating
- 4: very prompt and regular
- 5: outstanding, did more than his/her share

quantity of work: the amount of work done by the individual throughout the project
- 1: unacceptable
- 2: did just enough to get by
- 3: average volume of work
- 4: did more than was required
- 5: superior work production

overall evaluation: comparison with other team members
- 1: definitely unsatisfactory
- 2: below average but made an effort
- 3: did an average job
- 4: definitely above average
- 5: outstanding

Print team member names in alphabetical order (last name) and include yourself. Give numerical scores using the criteria above.

criteria names ⇨				
accuracy				
participation				
quantity of work				
overall evaluation				

Please write any other comments about each team member on the reverse side.

[adapted from team member evaluation form used at Bucknell University, July 2003]

Table 6. Fall Course Grading

n	average of points from class assignments (75%)
a	technical project advisor (25%)
t	team average for participation and progress
i	individual rating for participation and progress
[(n.75) + (a*.25)]* i/t*	grade in course, scaled for each team member

7. Summary and Conclusions

A summary of instruments described for assessment in a senior capstone design course and which ABET EAC Criteria they address are given in Table 7. Table 8 gives an overview of all assignments across the entire course sequence with an approximate timeline. The overview includes both assessment-related assignments and design-related assignments.

Table 7. Instruments and Criteria

assessment technique	*Criterion 3*	*Criterion 4*
fall survey of achievement vs. importance	a-k	
self-assessment assignment	c, g	culmination
ABET concerns assignment	g	constraints
student assessment of team functioning surveys	d	
peer review form for design reviews	c, g	
current events assignment	f, g, i	constraints
small group assessment	general	
spring exit survey	a-k	
final presentation assessment form	a, c, d, e, f, g, i, k	

Table 8. Approximate Timeline for Assignments

week	*ABET assessment*	*design deliverable*
Fall: 1	outcomes survey	professional biography
2		project description
3		team contract
4	self-assessment essay	system requirements
5	ABET concerns essay	
6		task list; team notebook
7		timeline/effort matrix
8		design diagrams (0 and 1)
9	technical specs/standards	design diagrams (2)
10	team assessment	notebook; design report
Winter: 2		revised timeline/status report
4	design review; peer assessment	interface specifications
6	current events essays	team notebook
8		test plan; response to design review
10	team assessment	revised design report

Spring: 7	small group assessment	team notebook; user manual
8	outcomes survey	test matrix
9	peer assessment	presentation and demo
10	final self and team assessments	final design report

Our next step toward closing the continuous quality improvement loop is to examine each outcome and determine to what degree the outcome is achieved across all instruments and program curricula, and look for opportunities for enhancement. The future work includes analysis of professional practice data; we have identified outcomes that are assessed by employers and students (summarized in Table 9) but have not coordinated the analysis with coursework portion of our curricula yet.

Table 9. Criterion 3 Outcomes in Professional Practice (Co-op) Evaluations

assessment technique	a	b	c	d	e	f	g	h	i	j	k
co-op employer assessment	●	●	●	●	●	●	●	●			●
co-op student assessment	●			●	●	●	●				●

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Biography

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Karen C. Davis is an Associate Professor of Electrical & Computer Engineering and Computer Science 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 shared the Dean's Award for Innovation in Engineering Education in 2002 with co-developers of an introduction to ECE course. She has advised over 30 senior design students and more than 20 MS/PhD theses in the area of database systems. 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.