Unit Plan for Assessing and Improving
Student Learning in Degree Programs

Unit: Electrical and Computer Engineering Department
Unit Head approval: Richard E. Blahut, Department Head **Date: May 10, 2008**

<u>SECTION 1: PAST ASSESSMENT RESULTS</u>

Changes or improvements made in your unit as the result of assessment results since 2000

Revisions to the undergraduate Electrical Engineering (EE) and Computer Engineering (CompE) Curricula: The ECE Curriculum Committee is charged with the task of steering the EE and CompE curricula in response to changes and developments in the discipline and initiating curricular modifications as needed. A major revision completed in the 2005 time frame has closely aligned the first two years of EE and CompE programs as follows: identical core ECE courses in the first two years; common math and physics sequences; re-organized required CompE sequence starting with a "bits-to-C" introduction to computing systems course (ECE 190), continuing with courses on digital logic and systems (ECE 290 and the lab course ECE 385), culminating with a pair of courses (ECE 391 and 411) on operating systems and computer architecture; CompE core requirements up to and including ECE 385 are also required under the EE program, where ECE 391 appears as one of the 3-of-5 semi-required courses; both programs share required 3rd year courses on probability, electromagnetics, and semiconductor devices.

Technical Electives rules have been changed to provide more freedom to EE majors in selecting their 35 Technical Elective hours from a broad list of courses offered across the university. The combinations of a broad Technical Electives list (managed by the ECE Curriculum Committee) and 12 hours of Free Electives provide a wide range of options to the students including the completion of technical or non-technical minors. Technical Electives under the CompE program are relatively more focused on ECE and Computer Science course offerings.

Professionalism and Ethics in Engineering: Curriculum Committee initiated actions to develop a more rigorous understanding of professionalism and ethics (outcome “f”) in preparing students for future careers engineering. A one-hour course in “Professionalism and Ethics in Engineering” was designed, piloted (Sp02) and launched as a permanent course (ECE 316). The course also contains a communication component designed to improve skills in writing and public speaking (outcome “g”). In addition, Professor Michael Davis (Illinois Institute of Technology, Chicago) conducted two faculty workshops on how to implement an integrated approach to professionalism and ethics within the engineering curriculum by embedding the material within regular courses. Subsequently, curricular units designed to raise student awareness of ethical issues in engineering practice have been introduced in several required core courses — ECE 110 (Introduction to Electrical and Computer Engineering), ECE 210 (Analog Signal Processing), ECE 290 (Computer Engineering 1), and ECE 445 (Senior Design Project).

Undergraduate research has received increased emphasis and many students are choosing to write a senior thesis documenting their research.

Enhanced student-faculty and student-student dialog: Increased opportunities for faculty-student interaction and feedback outside the classroom include scheduled student gripe sessions (open forum to air complaints), peer advising system (student to student); faculty mentors for each student, ECE-supported “Power Lunches” — students invite a faculty member to lunch for informal discussions; faculty / administrator lunches with officers of key student organizations (EKN, IEEE student chapter, ECE Student Advisory Committee, IEEE Women in Engineering, Women in ECE, etc.)

ABET Evaluation (2007): The objectives and outcomes of the undergraduate degree programs in ECE were reviewed by ABET in 2007 and found to be of exceptional quality overall.

Elimination of No-Thesis M.S. Degree Option: The no-thesis MS degree option was eliminated by faculty vote at the December 11, 2006 faculty meeting.

New PhD Qualifying Examination: The Graduate Committee identified a need to develop a flexible tool for assessing preparation and aptitude for carrying out research in the PhD program, and revamped the PhD qualifying examination procedure, beginning in Fall 2006. The old Qualifying Examination consisted of two written examinations, covering undergraduate coursework, and graduate-level coursework, respectively. This was replaced with an oral examination focused on written and oral presentation skills, and technical fundamentals that span topics related to the student's chosen area of research. The new Qualifying Examination provides an opportunity to assess a wider range of skills and aptitudes. The Graduate Committee is in the process of assessing the new Qualifying Examination using feedback from faculty.

New PhD Breadth Requirement: Beginning in Spring 2008 PhD students must now achieve a 3.5 GPA in three 500-level courses selected from three different areas by the time of the Ph.D. Preliminary Examination. The Graduate Committee has divided all ECE 500-level courses into the nine standard departmental as well as three additional areas (Optics, Mathematics and Robotics/AI).

SECTION 2: REVISED ASSESSMENT PLAN

(a) PROCESS: description of process followed to develop/ revise this assessment plan

The ECE Outcomes Assessment Plan that was in place in 2000 had been developed simultaneously with preparation for the ABET (Accreditation Board for Engineering and Technology) Evaluation visit in Fall 2001. Because ABET had just instituted a new system of assessment criteria labeled "EC2000," the assessment process for the 2001 ABET visit had to be rebuilt from the ground up. This reconstruction, coordinated by the Associate Head for Instructional and Graduate Affairs, featured extensive faculty involvement through the constitution of a departmental ABET Evaluation Committee with faculty membership consisting of: the Associate Head for Instructional and Graduate Affairs (Chair); the Chairs of the Department's seven Instructional Area Committees; the Associate Head for Undergraduate Affairs ; the Chair of the Departmental Curriculum Committee; and the Faculty member in charge of the Senior Design Project Laboratory course.

This rebuilt assessment process was highly successful, and the 2001 report of the ABET external evaluators found no deficiencies, weaknesses, or concerns. Since the assessment process leading to the 2007 ABET evaluation would be derived from the successful process and procedures put in place for the 2001 evaluation, it was decided that a smaller committee could more effectively plan and coordinate these preparations. The ABET executive committee, appointed in the fall of 2006, is chaired by the Associate Head for Administrative and Instructional Affairs, and includes the Associate Heads for Undergraduate Affairs and for Graduate Affairs, the current and past two chairs of the curriculum committee, and the former Associate Department Head who directed the 2001 process. Meeting weekly, this committee planned and coordinated the implementation of the process for the 2007 ABET visit, while interacting with the ABET Evaluation Committee and the curriculum committee as needed, as well as working directly with the course directors and the faculty. Through their membership on the ABET Executive Committee, the ABET Evaluation Committee and the Curriculum Committee, which oversees all matters pertinent to undergraduate curricula and courses, numerous faculty members are continuously and directly involved in carrying out the ECE process. All faculty members are involved by developing their course goals and instructional objectives, and by completing their self-assessment of course outcomes, which are the essential components of the ECE process for assessment and improvement of the curriculum and the quality of instruction.

(b) STUDENT OUTCOMES:

The mission of the Department of Electrical and Computer Engineering is to serve society through excellence in education, research, and public service. We provide for our students an education in electrical and computer engineering, and we aspire to instill in them the attitudes, values, and vision that will prepare them for lifetimes of continued learning and leadership in their chosen careers. Through scholarship the Department strives to generate new knowledge and technology for the benefit of the State of Illinois, the nation, and beyond. (The complete ECE Mission Statement is provided as attachment 1.)

In fulfillment of this mission, we strive to achieve the student learning outcomes listed below. [These outcomes correspond to the program outcomes used in the ABET assessment process for electrical engineering (EE) and computer engineering (CompE).] The letter designations a-q are used to relate these outcomes to specific Course Goals and Instructional Objectives and to the instructor self assessments discussed in section 2(c).

a. Ability to apply knowledge of mathematics, science, and engineering. Ability to design and conduct experiments as well as analyze and interpret data
c. Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
d. Ability to function on multidisciplinary teams
e. Ability to identify, formulate, and solve engineering problems
f. Understanding of professional and ethical responsibility
g. Ability to communicate effectively
h. Broad education necessary to understand impact of engineering solutions in a global, economic, environmental, and societal context
i. Recognition of the need for and ability to engage in lifelong learning
j. Knowledge of contemporary issues
k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
l. Knowledge of probability and statistics, including applications to EE or CompE
m. Knowledge of mathematics and of basic and engineering sciences necessary to carry out analysis and design appropriate to EE or CompE
n. Knowledge of advanced mathematics (EE) and/or discrete mathematics (CompE)

For graduate students the desired objectives are all of the above in their undergraduate preparation, plus the following:
o. Carry out independent research

p. Function effectively in leadership roles in their professional careers
q. For Ph.D. graduates entering academia, function effectively as instructors (in addition to a-p)

(c) MEASURES AND METHODS USED TO MEASURE OUTCOMES:

Formal external reviews: The undergraduate degree programs of the ECE department undergo rigorous evaluation for accreditation by ABET on a six year cycle, with the most recent review having occurred in 2007, and the next one anticipated in 2013. The evaluation is based on a detailed written Self Study Report (475 pages in 2007), and a three day campus visit by a team of ABET evaluators. Many of the department's assessment methods have been developed and refined in response to these periodic ABET evaluations. In addition, the ECE department will soon undergo an external review commissioned by the Dean of the COE. A panel of NAE members has been constituted and has requested detailed information concerning all aspects of the instructional, research, and service activities of the department prior to an on-campus review to be conducted in October 2008.

Departmental student survey: This annual survey asks all ECE undergraduate students to rate how effective the ECE department and UIUC have been in helping students achieve the a-n outcomes (attributes of an engineer), and it has been carried out each year from 2000 to 2007. (The results are shown in attachment 2 for both the EE and CompE programs.) Used as a primary benchmark in the 2007 ABET assessment, it will be continued annually.

Meetings and conversations with students: Student feedback concerning the effectiveness of our curricula and the quality of the learning environment and student life is also obtained through meetings with student committees such as the ECE Student Advisory Committee (ECESAC), the UIUC student chapters of IEEE, and Eta Kappa Nu, and by organized lunch meetings of students with department administrators and other faculty chosen by the students. These continuing activities are part of our future plans to meet expectations for upcoming accreditation assessments.

Alumni survey: The departmental alumni survey asks our alumni who graduated between five and ten years ago to assess the department's success at achieving its four program educational objectives and the 14 a-n student learning outcomes. The survey also asks questions about employment status, educational influences at ECE Illinois (instructors, textbooks, labs), and alumni outreach.

Alumni interactions/conversations/feedback: The ECE Department has over 20,000 living alumni and many of them are leaders in industry, faculty members in educational institutions, or founders of business enterprises. They provide valuable feedback concerning our objectives, outcomes and other issues. Feedback is provided through our Alumni Board meetings, extensive faculty interactions with industry through affiliate groups, technical conference participation, and research collaborations, and similarly with faculty at other universities that accept our students for graduate school and, in many instances, employ our graduates as faculty members and higher level administrators. These interactions provide a continuous flow of anecdotal information regarding the quality of our graduates and their performance in the workplace.

Faculty end-of-course self-assessment: The faculty survey was modified subsequent to 2001; it now takes the form of an end-of-course self-assessment that asks the instructors to assess on a numerical scale how effectively their respective courses (as taught in the semester just concluded) helped students to achieve each of the a-n program outcomes, as applicable. In addition, they are asked to write a brief narrative assessment of their performance in terms of the course goals and instructional objectives that are linked to the a-n outcomes. Examples are provided as attachment 3.

GRE assess the preparation of our graduates for graduate study and research: GRE scores of our graduates who apply to our (ECE Illinois) graduate education programs can be compared to published national averages; we have recently obtained the GRE scores for all of our graduates who took the exams in the years since the 2001 ABET evaluation.

Data concerning the recruitment activities and starting salaries of our graduates: The College of Engineering Career Services Office collects these data for our graduating students who use their services in obtaining employment. Summaries of these data (e.g. numbers of interviews and job offers, starting salaries, etc.) and comparisons with national averages are reported to the engineering departments.

National and international surveys and rankings of university academic programs: National rankings of EE and CompE programs such as those of the U.S. News and World Report provide a valuable external perspective on the overall quality of our degree programs, although they are not broken out according to our a-n student learning outcomes.

Assessments unique to the Graduate program: Ability to conduct independent research is assessed by a PhD Qualifying Examination, a PhD Preliminary Examination, and a PhD Final Examination. The Qualifying Examination committee consists of three members of the graduate faculty (the research advisor is not included on this committee), and the Preliminary and Final Examination committees include at least four members of the graduate faculty. In addition, ECE is participating in an ongoing effort to develop new methods for assessing degree completion and attrition patterns in graduate programs, and to develop targeted intervention strategies with special emphasis on women and underrepresented minority populations. This activity is being carried out under the auspices of a Phase II PhD Completion Project grant to the Graduate College from the Council of Graduate Schools. ECE is one of fourteen programs selected from across campus to contribute to this effort.

SECTION 3: PLANS FOR USING RESULTS

(a) PLANS: Brief description of plans to use assessment results for program improvement.

Plans call for continued use of assessment measures listed above with feedback to the Curriculum Committee concerning recent curriculum revisions. Committee has also recommended revision of gateway courses concerning solid state devices (ECE 440) and electronic circuits (ECE 442) to realign these courses with the 300 level. The initial course in electromagnetics (EC E 329) is also being revised to better complement the planned ECE 340 and ECE 342.

The Graduate Committee will review and critique the first four semesters of operation under the new Ph.D. oral qualifying exam and recommend any needed changes in this new system.

(b) TIMELINE FOR IMPLEMENTATION:

Two experimental versions of the 300-level revision of ECE 440 will be offered in F08.

Any recommended changes in the qualifying exam format would probably be implemented in the F09-Sp10 time frame.

ECE Mission Statement

The mission of the Department of Electrical and Computer Engineering is to serve society through excellence in education, research, and public service. We provide for our students an education in electrical and computer engineering, and we aspire to instill in them the attitudes, values, and vision that will prepare them for lifetimes of continued learning and leadership in their chosen careers. Through scholarship the Department strives to generate new knowledge and technology for the benefit of the State of Illinois, the nation, and beyond.

The mission of the ECE Department continues a tradition of excellence in the above areas by honoring and continuously renewing our four interconnected commitments:

To Students:

by fostering an environment that enables prospective engineers to pursue their goals in a program that is rigorous and challenging, open and supportive

by providing undergraduates with the broad education necessary for productive employment in the public or private sectors or to pursue advanced degrees

by providing undergraduates with a deep understanding of both fundamentals and important current issues in electrical and computer engineering

by engaging graduate students with focused instruction and research opportunities in preparation for careers in industry, academe, and public service

To Faculty:

by providing human support and material resources needed for them to develop as dedicated scholars, devoted educators, and innovative researchers so that they may enjoy long, fulfilling, and challenging careers

by supporting a collegial environment rich with autonomy, teamwork, discourse, and inquiry

To Alumni:

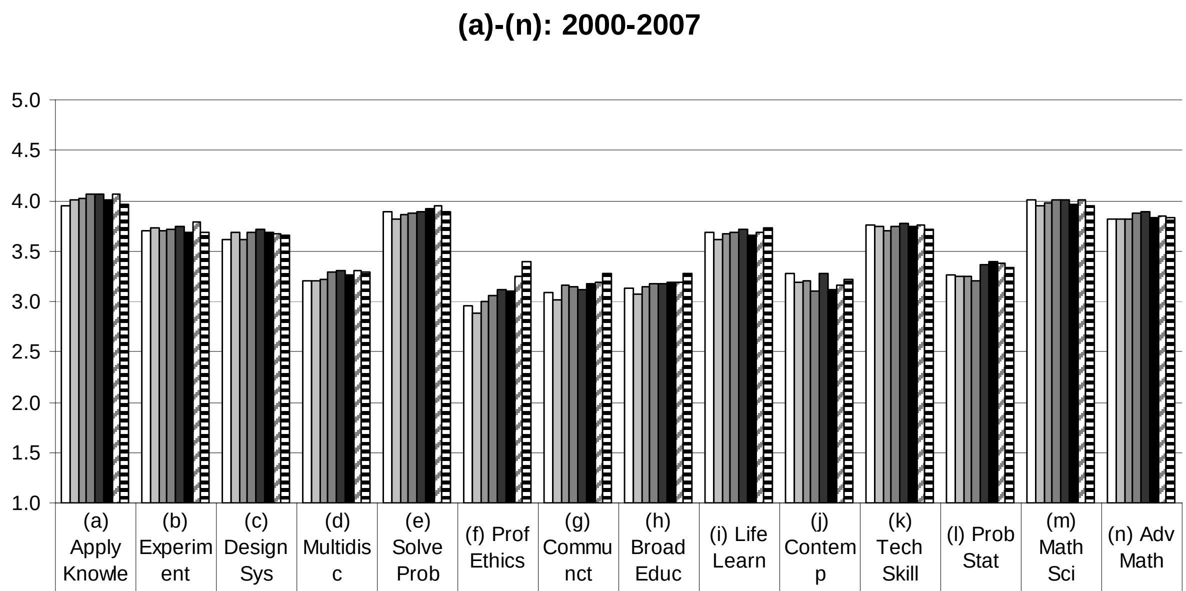
by seeking to maintain productive ties with our students after graduation in order to enhance their opportunities for lifelong learning and leadership, as well as to benefit from their skills, knowledge, and experience

To the State of Illinois:

by supporting the historic land-grant mission of the University

by working toward our ultimate goal of enhancing the quality of life for all

Attachment 1: ECE Mission Statement.

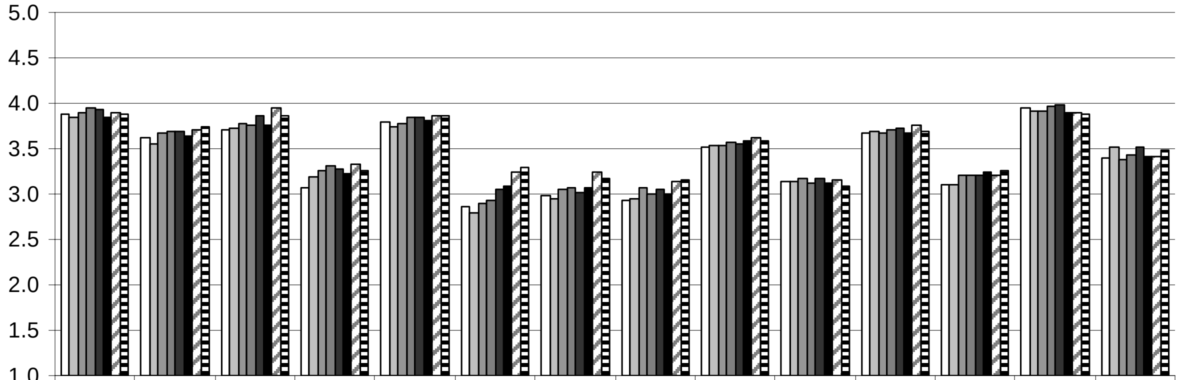


	(a) Apply Knowle	(b) Experiment	(c) Design Sys	(d) Multidisc	(e) Solve Prob	(f) Prof Ethics	(g) Communct	(h) Broad Educ	(i) Life Learn	(j) Contemp	(k) Tech Skill	(l) Prob Stat	(m) Math Sci	(n) Adv Math
2000	3.95	3.71	3.62	3.21	3.89	2.96	3.09	3.14	3.68	3.28	3.76	3.26	4.00	3.81
2001	4.00	3.73	3.69	3.21	3.82	2.89	3.01	3.08	3.62	3.19	3.74	3.24	3.95	3.82
2002	4.02	3.70	3.62	3.23	3.86	3.00	3.17	3.14	3.67	3.20	3.70	3.25	3.98	3.82
2003	4.07	3.72	3.69	3.29	3.87	3.06	3.15	3.17	3.69	3.10	3.74	3.20	4.00	3.88
2004	4.06	3.74	3.72	3.31	3.89	3.11	3.11	3.18	3.72	3.27	3.77	3.36	4.01	3.89
2005	4.00	3.69	3.69	3.27	3.92	3.11	3.17	3.18	3.66	3.12	3.74	3.40	3.96	3.82
2006	4.07	3.78	3.66	3.31	3.94	3.25	3.18	3.18	3.69	3.16	3.76	3.38	4.01	3.84
2007	3.96	3.69	3.66	3.30	3.88	3.40	3.28	3.27	3.73	3.22	3.71	3.33	3.96	3.84

Comparison of mean responses for years 2000 through 2007 from EE undergraduates to the question *How much have the ECE department and UIUC helped you develop the following attributes of an engineer? Fill in a number between 1 ("not at all") and 5 ("a great deal").* The attributes correspond to outcomes a-n.

Attachment 2: ECE student survey results for 2000-2007

(a)-(n): 2000-2007

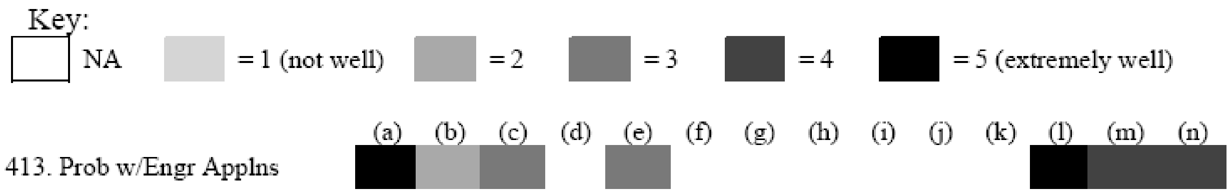


	(a) Apply Knowle	(b) Experi ment	(c) Design Sys	(d) Multidis c	(e) Solve Prob	(f) Prof Ethics	(g) Comm unct	(h) Broad Educ	(i) Life Learn	(j) Conte mp	(k) Tech Skill	(l) Prob Stat	(m) Math Sci	(n) Disc Math
2000	3.88	3.62	3.71	3.07	3.80	2.87	2.98	2.92	3.52	3.14	3.67	3.10	3.95	3.39
2001	3.85	3.56	3.73	3.18	3.75	2.80	2.95	2.95	3.53	3.13	3.69	3.11	3.92	3.51
2002	3.90	3.68	3.78	3.26	3.78	2.90	3.05	3.07	3.53	3.18	3.68	3.21	3.92	3.39
2003	3.95	3.69	3.76	3.31	3.85	2.94	3.07	3.00	3.57	3.12	3.70	3.21	3.97	3.44
2004	3.92	3.69	3.87	3.27	3.85	3.06	3.02	3.05	3.55	3.17	3.72	3.21	3.98	3.51
2005	3.85	3.65	3.75	3.23	3.82	3.09	3.07	3.00	3.58	3.12	3.68	3.24	3.90	3.42
2006	3.90	3.72	3.94	3.33	3.87	3.25	3.25	3.14	3.63	3.15	3.76	3.22	3.90	3.41
2007	3.88	3.74	3.86	3.26	3.87	3.29	3.17	3.16	3.58	3.09	3.69	3.25	3.88	3.49

Comparison of mean responses for years 2000 through 2007 from CompE undergraduates to the question *How much have the ECE department and UIUC helped you develop the following attributes of an engineer? Fill in a number between 1 ("not at all") and 5 ("a great deal")*. The attributes correspond to outcomes a-n.

Attachment 2: ECE student survey results for 2000-2007

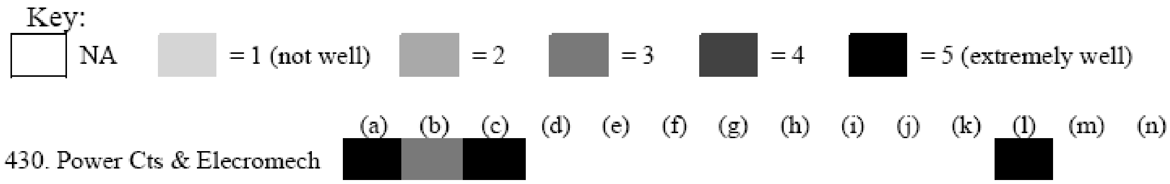
Example from ECE 413: Probability with Engineering Applications



We comment on the primary attributes, (a),(l),(m), and (n-EE), (n-CompE) and the secondary attributes (b), (c), and (e), designated for the course. Throughout the course, mathematics is used extensively. The first six weeks of the course cover much material in discrete mathematics, including set theory, Venn diagrams and Karnaugh maps, combinations and permutations, and binomial coefficients and their properties. See problem sets 2-5. The middle of the course uses many properties from calculus of functions of one variable, such as the chain rule, Taylor's series, and integration by parts. The last five weeks of the course, which deal with jointly distributed random variables, is based extensively on calculus of two or more variables, including the use of integration over regions in the plane, and the determinant of a two by two Jacobian matrix. Thus, we feel the course addresses attribute (a), the ability to apply knowledge of mathematics, science, and engineering, extremely well, in particular the knowledge of mathematics. For the same reasons, we estimate that the course addresses attributes (m) and (n-EE), (n-CompE) well (rating of 4). The entire focus of the course is on the use of basic probability theory, and applications in statistics including confidence intervals, hypothesis testing (see problem 1 on exam 2 and problem 4 on the final exam), parameter estimation (see problem 3 on exam 1), and use of the central limit theorem (see problems 6 and 7 on problem set 13), and linear and nonlinear minimum mean square error estimation (see problem 7 on the final exam). Thus, we feel the course addresses attribute (l) extremely well. The material on minimum mean square error estimation, law of large numbers, central limit theorem, and correlation coefficient covered in the course contributed somewhat to the student's ability to analyze and interpret data, so that we feel the course somewhat addresses attribute (b) (rating of 2). The material covered on failure rates and reliability of systems (see problem set 7), including the use of Bayes formula, plays a key role in design for manufacturability, testing, and safety, so that we feel the course addresses attribute (c) (rating of 3). Finally, much of the course deals with how to break large problems into smaller, manageable pieces, as illustrated in the material on system reliability (problem set 7), so that we feel the course addresses attribute (e) (rating 3) as well.

Attachment 3: Examples of end-of-course faculty narrative self-assessments

Example from ECE 430: Power Circuits and Electromechanics



Student performance in ECE430 is evaluated through quizzes and exams. In addition, the course is divided into two sections to provide more direct student contact with the instructors and teaching assistant. Both sections are given the same assignments and exams; the differences in performance are not statistically significant. As in the past few semesters, quizzes are given in lieu of collecting assigned homework.

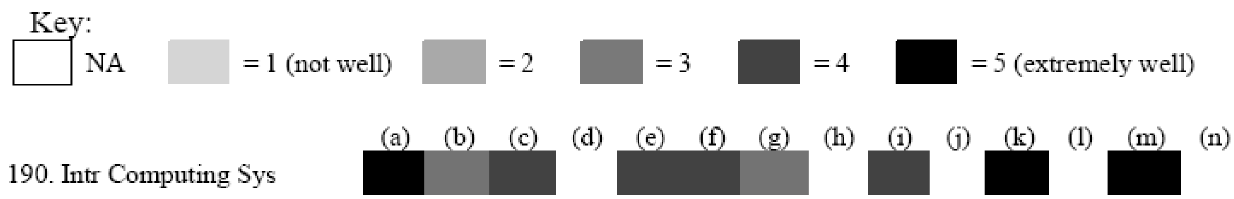
There are three segments of the course. The first segment expands on basic circuit theory learned elsewhere (particularly in ECE210). The topics emphasize the use of basic circuit principles and integral calculus on new systems—outcomes (a) and (k) primarily, with some design (c). Performance was evaluated with five quizzes and an exam. Exemplary homework problems include problem 2.18 on homework 1 (outcome (a)), problem 3.3 on homework 3 (outcome (k)), and problem 3.20 on homework 5 (outcome (c)). This segment is also included on the final, problems 1 and 2 (outcomes (a), (k)).

The second segment focuses on electromechanical energy conversion processes and is more mathematical. Again, outcomes (a) and (k) were primary. Real-world example problems exposed students to experimental analysis (outcome (b)). Performance was evaluated with three quizzes and an exam. Exemplary homework problems include problem 4.7 on homework 7 (outcome (a)), problem 4.16 on homework 7 (outcome (k)), and problem 4.23 on homework 8 (outcome (b)). This segment is included on the final, problem 5 (outcomes (a), (k)).

The final segment builds on both circuit theory and electromechanics to analyze electric machines. The material here calls for a broader system view, so in addition to outcomes (a) and (k), significant design opportunities (c) were explored. There were two quizzes on this material. The final exam, while cumulative, stressed the last third of the course. Exemplary homework problems include problem 6.4 on homework 9 (outcome (a)), problem 6.11 on homework 10 (outcome (k)), and problem 7.24 on homework 11 (outcome (c)). Final exam problems 3, 4 (both for outcome (c)) and 6 (outcomes (a), (k)) test student learning for this segment.

Attachment 3: Examples of end-of-course faculty narrative self-assessments

__Example from ECE 190: Introduction to Computing Systems__



This self-assessment is based on statistics collected from examinations, informal weekly feedback from TAs and lab assistants as to student progress and understanding, monitoring of the public forum (web board). The assessment values are relative to the outcome of my previous efforts at teaching the same material (in Fall 2003, Spring 2004, Fall 2005, and Fall 2006).

Overall, I was pleased with student performance this semester. Test results were generally fairly good, with only a handful of areas of difficulty. MP performance was also generally quite high, and adoption of tools and effective approaches to software development was much more widespread and earlier in the semester (based on feedback from my staff and my previous experience) than in previous semesters, in part due to a stronger emphasis placed by me on the value to the students of using tools and developing proper programming habits. Between the exam results and the reduced pain in the labs this semester, I decided to award myself 5's in **(a)**, **(k)**, and **(m)**.

Students were also more active during the lectures and on the web board than in some previous semesters, and were clearly willing to take the lead both in helping each other and in finding information on their own, so I scored myself a 4 on **(i)**. I'm not sure that I can do better in a freshman course, so I have nothing constructive to suggest to reach 5.

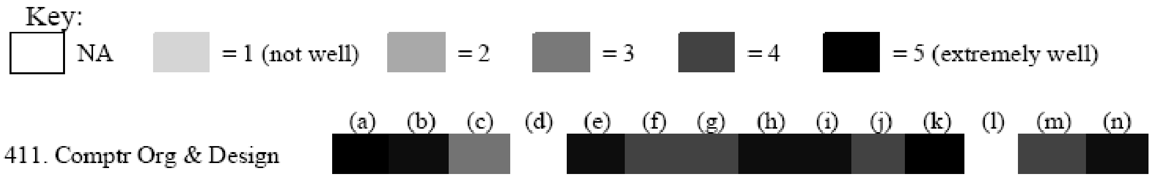
As always, many of the students did not test their software adequately (it's a lot to ask in a first-semester programming course, but we have high expectations), thus the score of 3 on **(b)**. Students also seemed to struggle a bit more than I hoped (and score lower than I'd like) with the largest machine problem (MP4, a two-pass assembler), so I gave myself a 4 on **(c)** and **(e)**. We probably need to give them more extensive case studies and examples, or perhaps just set more realistic goals, since we also emphasize these topics in later courses (at least for the CompE's).

Violations of academic integrity were fewer this semester, and students took their responsibilities of providing adequate documentation, being timely in assignments, etc., well. We could perhaps be more explicit in relating their work to their future professions, though, so I picked 4 for **(f)**.

Finally, while the students did on average put more effort into communication, their communication skills are still pretty poor, mostly as evidenced by their ability to phrase short answers when asked about engineering tradeoffs on examinations, so I gave myself a 3 on **(g)**. We don't actively teach such skills—we only give opportunities for their use—nor is it clear that we should, so, again, I have no constructive ideas here.

Attachment 3: Examples of end-of-course faculty narrative self-assessments

Example from ECE 411: Computer Organization and Design



The basis for assessment was students' performance on the midterm and final exams, their performance on the three design projects (the third one being a very substantial group-based project), classroom discussions, interviews conducted at the end of semester (details below), conversation with students during the office hours and the labs. Below I address through narrative and examples how the various course outcomes are addressed:

Outcomes a and b: The course has a very strong laboratory component where the students are given three machine problems (MPs). MP1 involves understanding the LC3b instruction set architecture (ISA), playing with basic CPU design written in VHDL, and getting familiar with the design tools that they use for MP2 and MP3. MP2 involves adding a memory subsystem (specifically caches) to the basic CPU design. MP3 involves building, along with group member(s), a fully pipelined processor that supports stalling and forwarding. Please find the three MPs attached herewith. These MPs are done in parallel with the lectures on the concepts of ISAs, caches, and pipelining. Hence, the MPs give the students a direct opportunity to apply the computer engineering lessons that they learn in the lectures thereby addressing outcome a. The correctness of their processor components, e.g., caches, etc., as well as execution is tested through observing/probing the intermediate values in various latches over time. The probed values also effect various design decision, in turn. The requirement to do these experiments based on their interpretation of data directly addresses outcome b.

Outcome c: While we encourage the MP3 designs to be feasible/reasonable in terms of design costs, the constraints are not a part of the problem specification itself at this point. Hence, outcome c is not addressed fully at this point. The instructor does discuss the design/verification/economic costs of various architectural decisions in the lectures, however. For example, the motivation for multi-core architectures was discussed largely in economic terms.

Outcome e: The ability to identify, formulate, and analyze engineering problems is tested directly in the MPs. For example, there are no constraints set in terms of how to implement forwarding or branch prediction (please refer to MP3 document). Different groups use very different approaches. Outcome e is also addressed through the exams. For example, problem 2D on the second midterm exam (attached herewith) asks the students to come up with a branch predictor that targets aliasing, history, as well as branch correlation. The only constraint set is the overall size of the predictor. The students are required to formulate this problem in a way that can be mapped directly to a design.

Outcome f: MP3 is expected to be done cooperatively in groups of 2 or 3. Completing the design successfully requires every team member to contribute. This is indeed done in most cases as evidenced by the peer reviews that the students were asked to do (a peer review form is attached herewith).

Outcome g: Ability to communicate effectively was directly tested during the interviews that the instructor conducted with each student at the end of the semester. Students were interviewed on different architectural concepts learnt through the lecture as well as their familiarity with MP3 designs. Points were earmarked specifically for presentation skills.

Outcomes h i j: The last few slides of every lecture specifically covered a specific architecture (it was called "computer of the day" section of the lecture) and its societal impact. For example, when LYON machines were discussed, the instructor related it to the concept of outsourcing. This directly addressed outcome h. The "Computer of the day" section covered machines starting with the most primitive ones (humans) to some of the futuristic ones (e.g., quantum computers). Students were also tested on this (Problem 1 of the final exam, attached herewith). This was intended for the students to recognize the need to do lifelong learning of computer architectural concepts in relation to technology. This directly addressed outcome i and j.

Outcome k: MPs (as described above) require the use of the latest CAD tools thereby directly addressing this outcome.

Outcome m n-CompE: Students were tested in exams on analyzing computer systems qualitatively. For example, problem 5 on exam 2 (attached herewith) requires the students the students to estimate the impact of stalls and forwarding on processor performance. Similarly, problem 5 on exam 1 (attached herewith) requires the students to estimate the benefits and pitfalls of pipelining quantitatively. MPs also involve applying the knowledge of discrete mathematics as all component designs require building state machines. Hardware minimization (and hence improving the cycle time) also often involves representing state machines as Karnaugh maps.

Attachment 3: Examples of end-of-course faculty narrative self-assessment