2006-1841: INTEGRATED SYSTEM-LEVEL DESIGN IN ELECTRICAL ENGINEERING

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Integrated System-Level Design in Electrical and Computer Engineering

Abstract

This paper describes an NSF-sponsored department level curriculum reform project in the Electrical and Computer Engineering Department at the University of Utah. The project focuses on developing system-level design projects (mostly labs, but a few software-only projects) that integrate ideas within a class, between classes, and in some cases between disciplines. Written and oral communication is also stressed throughout this program. Materials are available for use by other educators via the PI (Furse) or the website[1].

Introduction

This paper reports on a department level curriculum reform project to integrate system-level design projects throughout an otherwise relatively traditional undergraduate electrical and computer engineering program at the University of Utah. Engineering students commonly receive a good fundamental education covering a relatively diverse set of topics both in and outside their direct discipline. Relatively few experiences exist in their formal education for combining these diverse concepts into a functional engineering system, however this is exactly what they are expected to do upon graduation. This project integrates system level design experiences at all levels of the engineering curriculum in several ways:

- Integrate individual labs within a course into a system-level design
- Integrate multiple courses via system-level design lab projects.
- Integrate multiple courses through teaming on projects
- Enhance the junior-level design experience with formal training in project management, entrepreneurialism, and system integration. (This is an *interdisciplinary initiative* between the Colleges of Business and Engineering.)
- Utilizing an enhanced "Write/Speak to Learn" program to help the students better understand the systems they design.

Methods

The ECE curriculum is relatively traditional and is shown in Table 1. All of the required ECE courses already include a laboratory component, and it is these laboratories that are being adapted to include project-based system designs. Typically, the basic concepts being taught in the labs remain very similar to what they were without the system level design, however these basic concepts are integrated to build a device. For example, in the Electromagnetics course, the lab always included measurement of impedance, power attenuation, antenna matching, etc. Now, in conjunction with the Signals labs, the students build a prototype communication system for a cardiac pacemaker. Combining these two courses allows the students to see how each set of otherwise disparate concepts are applied, and how they are related to each other. Other projects include a Biosensor system, AM Broadcasting system, Frequency Shift Keyed Wireless Local Area Network (FSK WLAN), Magnetic Levitation Control System, Motor Control

System, Triband Antenna Designs, and more. These projects will be briefly described below, and details are provided online[1] for professors interested in replicating them in their own courses.

Projects

The following projects have been developed so far in this project:

Cardiac Pacemaker Communication System[2] ***Intro to Electromagnetics /Systems***

The basic EM and Systems labs were combined to allow the students to design the major system components and experiment with a functional system for an FSK communication system for an implantable cardiac pacemaker communication system. Students design the receiver and transmitter, the antennas, tissue simulant material, and determine the power link budget.

Dual Band Patch Antenna Design ***Antenna Theory***

The students designed dual-band patch antennas for use for wireless telephone (835 and 1900 MHz) and wireless LAN communications (2.45 and 5.5 GHz). These antennas were designed using the Sonnet-Lite 10.51 software available on the internet. The microstrip antennas were fabricated using an etching system and tested for their performance in our newly renovated anechoic chamber.

System Simulation of Software Radio ***Software Radio***

In Spring 2005, NSF support was used in the development of a new Software Radio class. We developed some Simulink and MATLAB software for the class. There is no lab in this class. However, there is a big project component. 50% of the grade comes from the class project. In addition, as a result of the developments in the software radio class, this semester we came up with a phase lock loop (PLL) experiment for 3500 class. Current development includes integration with the PLL project in ECE 3510.

Spread Spectrum Communication Systems[3] ***Wireless Communication***

This project created a set of labs for the Wireless Communciations course that allowed students to simulate and prototype digital spread spectrum communication systems. These labs are an adaptation to labs originally funded by NSF at Polytechnic University[4].

Wireless Local Area Network[11] ***Microwave I***

Students build an FSK WLAN from microstrip components. This is an adaptation of labs designed at Brigham Young University and Utah State University.

Table 1: ECE Project-based Curriculum

Key:
Individual course project
Multiple course project
Senior design sequence

Freshman Fall		Spring	
Intro to Unix	0.5	Introduction to EE & CE (BioSensor System)	4.0
Program Design C	4.0	Introduction to MATLAB	1.0
Calculus I	4.0	Calculus II	4.0
Academic Writing	3.0	Physics for Sci. & Eng. I	4.0
E-LEAP/Div/Hum. Gen Ed	3.0	E-LEAP/SS/Ethics Gen Ed	3.0

Sophomore Fall		Spring	
Fund. of Elect. Circuits	4.0	Fund. of Eng. Electronics (AM Broadcasting)	4.0
ODEs and Linear Algebra	3.0	Fund. of Dig. Sys. Design	4.0
Physics for Sci. & Eng. II	4.0	Calculus III	3.0
General Chemistry I	4.0	American Institutions	3.0
General Chemistry I Lab	1.0		

Junior Fall		Spring	
Fund. of EM & Trans Lines (Cardiac Pacemaker Communication System)	4.0	Eng. Prob. & Statistics	3.0
Fund. of Signals & Systems (Cardiac Pacemaker Communication System)	4.0	Prethesis	0.5
Junior Seminar	0.5	Professional Writing	3.0
PDEs for Eng. Students	2.0	Intro to Quantum Theory	3.0
Elective: VLSI (VLSI Design)	4.0	Thermodynamics I	2.0
		Elective: Wireless Comm (Spread Spectrum Comm System)	4.0

Senior Fall		Spring	
Senior Thesis I	2.0	Senior Thesis II	3.0
Elective: Microwave Eng I (FSK WLAN)	3.0	Elective: Numerical Methods (Microstrip Modeling)	3.0
Elective: Antennas (Triband Antenna Design)	3.0	Elective: Control Systems (Magnetic Levitation Control System)	3.0
Elective: Business/Eng (Business Plan)	1.0	Elective: Business/Eng (Business Plan)	1.0
Fine Art Gen Ed	3.0	Fine Art Gen Ed	3.0
Humanities Gen Ed	3.0	Social Science Gen Ed	3.0
Elective: Control of Motors (motor control system)	3.0	Elective: Software Radio (Software Radio System)	2.0

Research IN the Classroom ***Numerical Electromagnetics***[5]

In an effort to see what the student response would be to bringing research directly into the classroom, one of the projects in this course was adapted to answer a potentially publishable research question. Students each wrote a short response to the question, and the best short responses as determined by the class were combined into a research paper that has been submitted for publication.[6]

Magnetic Levitation Control System ***Controls***

Students build a simple magnetic levitation system, measure its system response, and design a software control system to allow the user to define the vertical rise of the levitated disk.

Motor Control System ***Controls***

In the area of controls, developments in the lab experience of students have been initiated along two tracks:

1) experiments with brushless DC motors for a course on the control of electric motors. The students integrate concepts from electronics, control, and programming.

So far, we have upgraded the data acquisition and control stations, planned the future labs and performed preliminary experiments with BLDC motors.

2) experiments with active noise control. An undergraduate student has assisted in obtaining impulse responses associated with acoustic noise propagation that will be used in simulations of active noise control systems.

BioSensor System[12] ***Intro to ECE***

Three new labs have been designed with a biomedical flavor for the introductory ECE courses.

1. Electromyogram: students measure voltage across electrodes placed on biceps. Teaches Kirchhoff's laws and simple op-amp circuits.
2. Flicker frequency for fovea vs. peripheral vision: students build circuit that flashes an LED at low rate. They determine fusion frequency where LED appears to be on all the time as opposed to flickering. They also observe that LED appears to flash twice as fast when viewed in periphery vs. straight on. Teaches simple RC circuits and op-amp used as comparator.
3. Circuit model of tissue impedance: students measure voltage drop (with tissue as part of voltage divider which thus gives current too) across biceps vs. frequency and then model the impedance of the tissue by fitting the data to an RC model. Teaches concept of impedance and calculations with impedance values.

QPSK Communication System ***Digital Signal Processing***

We are working on integrating a communications related sequence of projects into the DSP course (ECE 5530/6530) in the department. The key undertaking was a significant reorganization of the computing assignments for the course. We developed three modules that together allow the students to simulate a complete QPSK system in software. In these modules, the students apply a large number of concepts they learned on sampling, filter realizations, filter designs, discrete Fourier transform in their implementations. The placement of the three modules in the semester are such that the discussions of these concepts in class and the software realizations go hand-in-hand. The modules may be downloaded from the web.[7]

New Project-Based Courses

The following new courses have been / are being developed in this project:

Microsystems Course

A new course on microsystems packaging and system integration has been developed. Packaging, system integration and reliability studies are the topics tying together the entire canon of micro, nano, sensor and electronics technology courses. Packaging requires coupling knowledge and understanding from all science and engineering disciplines, a thorough understanding of system integration and the awareness of system and application/market requirements.

Embedded System Design

A new course has been developed combining two previous courses, and the labs have been completely overhauled. In these labs, the students designed simple systems using a Motorola 68HC11 microcontroller and peripheral hardware. They had to design both the hardware needed and assembly language software. Labs included design a keypad interface, a thread scheduler, a simple serial network, pulse generator, etc.

Business and Engineering Course

A year long business course was created to provide real-world, hands-on, technology-based product development consulting experience to advanced level MBA students and an initial experience with business concepts for juniors and seniors in engineering. MBA and engineering students sign up for separate courses. The course is team taught by ECE and Business. Bi-weekly lectures are given by several guest speakers with expertise on various aspects of innovative product developments such as business plan development, valuation & financial analysis, marketing research, project management, intellectual property and legal issues, and negotiation, teamwork and leadership. MBA students are assigned as "business consultants" to engineering student-teams working on new product development projects. While the technical nature of product development is the focus of work performed by engineering students, the MBA student collaborate with the engineering students to provide a rigorous analysis for the commercial viability of the project, and advise the project teams on business and management aspects of their projects.

The projects chosen for assessment are chosen and recommended by the university Technology Commercialization Office (TCO) and are based on UofU engineering research. Students sign non-disclosure agreements in order to gain full technical access to the projects.

Students are given a business plan template with instructions at the beginning of the course, and are encouraged to complete sections (marketing, technology description, financials, etc.) soon after the guest lectures on those topics. Plans are assessed by peer student teams, by the professors involved, and by the TCO. Students are graded on the quality of their assessment, not the identified business potential of the product they are assessing. Some of the plans recommend entrepreneurship, others licensing, and still others indicate that there is not a good business case for the product. Use of peer evaluation of the business plans means that all students will have had opportunity to see details of products in all of these categories.

Writing and Speaking Initiative[8,9]

The writing and speaking initiative in this project is administered through the Center for Engineering Leadership (CLEAR) in the College of Engineering . The CLEAR Center is an interdisciplinary collaboration between the Department of Communication, the University Writing Program, and the College of Engineering that fosters active learning of engineering material through speaking, writing, and teaming. In addition, CLEAR seeks to prepare engineering students to occupy positions of leadership, which require well developed interpersonal, oral, and written communication abilities. CLEAR also addresses ethical issues for engineers working in an increasingly technologically dependent and complex world where knowledge is applied to highly constrained problems affecting diverse interest groups with different values. CLEAR seeks to teach communication skills, foster ethical understanding, and expose students to the dynamics of teamwork (problem solving, conflict resolution, listening, accountability, etc.) in an effort to enhance their leadership potential, while simultaneously fostering a deep understanding of engineering material.

In contrast to other communication/engineering partnerships, the CLEAR program is unique in that communication instruction is conducted by graduate (Ph.D.) students (CLEAR consultants) from the Department of Communication and University Writing Program in the engineering classroom. Not only are these consultants actively involved in teaching the engineering students about communication and teamwork, they are in a sense educating engineering faculty throughout this process. In this model, CLEAR consultants utilize small blocks of time (15-30 minutes) a few times throughout the semester to teach students about a specific communication concept (such as how to write a good introduction for a lab report, properly reference background work, prepare a team work plan, or how to prepare a talk for a specific type of audience). Students then apply this concept immediately to engineering tasks already being taught in the course (system design, engineering documentation, defense of concepts, etc.). CLEAR consultants and the engineering professor work together to provide assessment and feedback on the student work, often through guided peer evaluation. This situated approach gives students' the opportunity to apply communication skills in context. This method also facilitates understanding of technical material at a higher level as students are required to explain it to their peers or other audiences. The writing initiatives have been incorporated into several required courses, and we are currently developing a course for the junior year that focuses on writing using the topics in the junior level courses as sources for writing materials and experiences.

The current writing and speaking initiatives are described below:

Freshman Level: Basic Oral Presentations and Written Documents

- Speech organization, experience, and numerical richness

- Written summaries, descriptions, observations, and questions

Lab Derivation Presentations and Write-to-Learn Activities (ECE 1000: Introduction to Electrical Engineering):

The first two semesters of the engineering core courses incorporate speaking and writing assignments into laboratory sections consisting of a familiar audience of 12-18 peers and a teaching assistant. During the weekly lab lecture, students utilize lab notebooks to write brief paragraphs summarizing the concept or process being discussed (circuit problems, solutions, Matlab^R codes) and describing their observations and questions. The following week, three to five student presenters relay the previous week's information in a five minute talk using the dry-erase board. It is the first technical, numerically rich presentation that they will give as engineers. It is also the first time students learn the importance of audience adaptation, as their audience is familiar with the material and must be convinced to be interested. They may also be critical if the student makes technical mistakes. As many of the students will not have previous experience writing or presenting at the college level, the assignment is evaluated as credit/no credit—similar to most first public speaking or writing assignments. The students give one presentation per semester and complete written speaker evaluations to offer immediate peer feedback. The process of evaluating their peers also improves their future presentations, as they become sensitized to the techniques that make presentations effective.

Sophomore Level: Advanced Oral Presentations and Written Documents

- Results-oriented, verbal explanation to a non-technical audience using visual aids
- Lab Reports, Presentation Proposal and Evaluation Memo

Laboratory Reports (ECE 2000: Fundamentals of Electric Circuits)

Students were introduced to lab notebooks during their first year course work, and they are now introduced to informal lab reports during their second. The CLEAR consultant, in short segments throughout the semester, explains each lab report section (i.e. introduction, methods and procedures, conclusion) and provides written instructions and examples, thus training students to write that particular portion. For each section, students follow a process of write-to-learn, draft, receive peer and consultant feedback, revise, and finalize the written document. The section for which students have received formal instruction and feedback is the only section that receives a grade for writing. As teaching assistants must grade the final document, and it is understood that form (writing) and content (engineering concepts) cannot be evaluated separately, the consultant works with the teaching assistants to develop criteria by which to asses the report holistically. By the end of the semester, students should be able to construct a complete lab report according to engineering standards.

"How it Works" Presentation and Accompanying Proposal and Memo (ECE 2100: Fundamentals of Engineering Electronics):

Students complete process steps that result in two written documents and one final oral presentation delivered in the laboratory setting. The individual, five minute presentation must include an explanation of the application, a summary of how that application works, a description of its significance in real world terms, and a schematic. The objective is to communicate an understanding of the material and to maintain audience interest; therefore, presenters must be able to field follow-up questions and comments.

Students begin the writing process by researching an electronic component and finding an application of interest (often a system) that contains the component. They then draft a proposal indicating the nature of their final oral presentation and a prose outline of the same. They send the written draft via email attachment to the consultant who makes comments to guide their revision process. Finally, they deliver the revised version of the proposal to the instructor, who approves it or suggests additional changes. Final written documents are evaluated on the basis of criteria determined collaboratively by students, teaching assistants, the consultant, and the instructor.

Students prepare to deliver their presentation by attending a practice session with the oral communication consultant. During the presentation, the speaker is evaluated by peers and teaching assistants, according to the five competencies of a technical presentation. After presenting, students collect the peer evaluations in order to analyze and synthesize the comments in a memo written to the instructor. In the memo, the student must evaluate his/her individual process and performance.

As presentations and written documents are initially evaluated by teaching assistants, these teaching assistants are required to attend a two-hour training session covering the fundamentals of assessing presentations and written documents.

Junior Level: Presenting Ideas and Creating Documents with Purpose

- Persuasive group presentations through creative problem solving, utilizing visual aids, and explaining complex concepts
- Rhetorically credible documents containing evidence, interpretation, and critical evaluation

Radio Frequency Safety Presentation[10] (ECE 3300: Introduction to Electromagnetics)

Students conduct general audience research (newspapers, magazines, textbooks, and internet) in order to create a brief "Talking Paper" that leads to a three-five minute oral presentation. Both brief and presentation are tailored for a non-technical, impromptu audience. The topic for the research and presentation is any issue of public concern surrounding radio frequency safety. Students address pertinent questions such as: Are cell phones safe? and Is it dangerous to live near high voltage power lines?

The timing of the assignment, before Thanksgiving or spring break, offers opportunities for students to wrap up research details, write their brief, and present their information to their family members as representative of a non-technical audience. This exercise serves to help students receive important feedback; additionally, it serves as a public relations tool, communicating to the student's family the nature and application of the technical information being learned, and thus demonstrating a return on educational investment.

After the break, the lecture class (~80 students) divides into small groups (~11 groups with ~7 students per group). First, students in the group quickly and informally deliver their "family" speeches to one another, using their written briefs as talking points. Second, they draw an "audience" from a hat of various potential audiences, to whom they must deliver the information. Such audiences might consist of a lawyer trying to sue a company, a 10 year old, or a new cell phone user considering moving into a home under high voltage lines. The groups are then given 3 minutes to create a new presentation, adapted to their new audience. In those three minutes, they must synthesize their original individual information into one collective whole and problem-solve to prioritize points for the most effective delivery. Finally, the speech is delivered by the group, or by a designated group member, to the class. The class, instructor, consultants, and teaching assistants provide feedback (oral and/or written) on the effectiveness of the presentation as determined by audience. Individual written briefs are collected by the consultant for comments relevant to research writing.

Assignments such as this demonstrate the practical application of newly acquired theoretical know-how to a public audience. This "in-class" practice models reality, in that safety concerns are always ripe topics for conversation, both for the non-technical public and the expert engineer. The assignment also teaches students how to analyze and determine what information is relevant for a specific audience and the importance of adapting it to that immediate audience.

<u>Bandwidth Allocation Design Project</u> (ECE 3500: Signals and Systems)

A brief, spontaneous, brainstorming session with the authors of this paper resulted in an effective assignment designed to address three realities. First, a professor of a traditional lecture course (~80 students) was frustrated with his students not fully appreciating the significance of a theoretical concept relevant to his course: bandwidth allocation as it applies to society. Second, the professor knew that speaking and writing to learn would encourage higher level thinking skills, such as creativity, and would help students understand concepts better. Third, the professor was leaving for a conference and had three "open" lecture days which could be used to convey the importance of this concept.

Given the need to address such realities, the professor finds a short article that demonstrates the costly and competitive economics and politics behind bandwidth allocation. The article is detailed, specific, and technical. Additionally, it uses many analogies, examples, and is simple to understand. Working collaboratively, the instructor, his two teaching assistants, and the consultant design a speaking assignment that challenges the students to create a new product for a particular bandwidth. This new product would need to be socially valuable and profitable enough to receive the competitive bandwidth allocation.

Students form groups, read the article outside of class, and, in class, develop products based on the professor's signals and systems course material. These products are then "sold" to the two teaching assistants who judge the technical, social, and economic merit of the designs as they observe each group during the first "open" class session. The best five group designs, from a total of 12 groups, are chosen to present their projects during the second open class meeting. During the third class session, 15 minute group presentations are delivered. From these five presentations, students vote for their favorite design, designating one top choice. All presentations are video-taped by the consultant and given to the professor on a DVD.

The authors have found students to be enthusiastic about this assignment. Their presentations are elaborate, with prototypes, PowerPoint slides, and video-taped segments created to make it appear as though the product were a functioning design. Such creative freedom is the catalyst for a successful merging of engineering and communication concepts. When it occurs late in the semester, after students have an opportunity to absorb critical concepts, it is an important move from pure to applied theory.

Meanwhile, a corollary writing assignment occurs in another course, attended by many of the same students in the signals and systems class.

<u>IEEE Transaction Articles – Critical Response Paper</u> (ECE 3910: Junior Design)

All ECE students are required to take a junior seminar course, designed to introduce students to local (and where possible, national) companies—their spokespeople, current projects, and professional issues. The purpose of this introduction is to prepare students to choose and pursue senior projects informed by real world concerns. As part of that preparation, students are required to critically explore an engineering issue of their choice, utilizing 3 IEEE transaction articles and resulting in a formal 8-10 page paper.

This assignment is a natural extension of, or corollary to, the signals and systems research on bandwidth. The same groups created for presentations there form teams to conduct collaborative writing research for junior seminar, possibly exploring the same safety issues. Together they gather pertinent articles, ask evaluative questions, discuss and interpret concepts, and work through design problems. The PDI serves as facilitator and resource: explaining the writing concepts involved, providing examples, modeling research inquiry, consulting, and commenting on drafts.

Both the bandwidth and transaction response assignments are effective because they require active learning and because they are intellectually complex. Students are required to develop and deliver two persuasive presentations to an authentic audience of their peers. They then use the thinking, designing, and teamwork strategies developed there to help them complete the junior seminar assignment, i.e. composing a formal, research document of transaction article length. Step by step, students use higher level thinking skills, such as creativity, interpretation, and evaluation to enhance their understanding of engineering concepts [18]. Finally, these assignments assist students as they transition to their culminating university experience: the senior design project.

Senior Level: Presentation and Document Synthesis for the Professional World

- Persuasive, numerically rich, results-oriented presentations that are visually sophisticated
- Formal, team-oriented documents that adhere to industry/professional standards

Senior Design Symposium Presentation and Writing Awards (ECE 4900, 4910: Senior Design)

Each senior must participate in a year-long design project consisting of approximately 200 hours of engineering research. These projects are designed to be accomplished either in groups (called clinics) or as individuals. Consultants work with senior design faculty and students as trainers and cheerleaders while students learn to research, write, design, and present collaboratively. In early April, students present their research projects during a formal symposium held at a conference center on campus. The students give 15 minute presentations to industry and faculty judges, with a five minute question and answer period immediately following. Two weeks following the symposium, students turn in a final written report. The oral and written presentation of their projects is required for graduation. The written report has been judged since the 1960s, awarding winners with a trip to present their papers at a western engineering conference. Historically, the oral component has not been judged equivocally.

However, in 2005, the oral communication consultant, supported by faculty members, secured funding for prizes and the hiring of eleven communication graduate students to judge the formal presentations. Based on the judges' comment sheets, three speakers were awarded cash prizes at the awards banquet dinner following the symposium. This change in design emphasized the quality of the professional presentations. This motivated students to compete for these prizes and encouraged practice and thoughtful presentation design. Additionally, the students appeared more poised and confident to the audience of family, friends, alumni, faculty, and donors.

Expected Outcomes

- *Increased freshman recruitment and retention*

It has been shown that an exciting freshman design project significantly improves freshman retention. In addition, our own senior exit surveys indicate that many freshmen who leave the program, especially those who are "non-traditional", women, or minority students, as these groups tend to prefer education that they perceive as relevant, society-oriented, and immediately applicable.

- *Increased student motivation*

Our student population is somewhat unique for social reasons. A majority of undergraduates are married and are supporting families. Most work at least part time, and many work full time or more. Many take a year off in the middle of their studies for missionary or other work. As a result, most students take 5-7 years to graduate. Maintaining student motivation in this over-committed student population is a significant challenge, and many professors have noted this problem. Our students' exit surveys indicate that they particularly like the courses that already have system-level projects, and that they desire additional system-level design projects, noting that these are the projects that keep their interest and perceived understanding of the material.

- *Increased knowledge acquisition and retention*

The nature of our student body also leads to significant challenges in knowledge retention. Students often have a span of multiple years between taking a prerequisite and the class that needs it. The ability to incorporate knowledge into projects across multiple classes is expected to significantly improve retention, as knowledge is continually renewed and utilized.

- *Increased system-level design understanding*

Our Industrial Advisory Board, recruiters and student employers, and the students themselves have noted the value of system-level understanding and the limited capability that our students have in this regard. This is not unique to our university and is a common concern in engineering education. This project formally demonstrates design at all levels of the curriculum and formally teaches project management in the junior year to expand the technical aspects of system-level design through a formal framework for evaluating and managing all aspects of a system.

Assessment Methods

Assessing the effectiveness of this approach is done as a descriptive exploratory field test of this innovative model of teaching, based on the following hypotheses and measurements:

Hypothesis 1: Students will demonstrate an increase in critical thinking and system-level understanding following the laboratory.
Hypothesis 2: Students will demonstrate more teamwork and peer support.
Hypothesis 3: Students will report an enjoyable learning experience.

Measures:

H1. Critical thinking test
(eg. Watson-Glaser Critical Thinking Appraisal. Other measures will be used for triangulation)
H1. Instructor evaluation
H1. Scores on exams
H1. Follow-on alumni surveys assessing motivation and perceived system-level understanding
H2. Self-evaluation of teamwork
H2. Team rating tool
H2. Observations of team activity (refine & itemize)
H3. Course evaluations with comments
H3. Test of self-confidence
H3. Test of performance fear
H3. Surveys of incoming freshmen (to assess recruitment) and follow-on surveys of students who leave the program both before and after implementation of this curriculum.

Acknowledgements

This work was supported by the National Science Foundation (EEC-0431958) and by the William and Flora Hewlett Foundation. Virtually all of the professors and their TAs in the Electrical and Computer Engineering Department are participating in and contributing to the development of these projects.

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