2006-1390: REDESIGN OF THE CORE CURRICULUM AT DUKE UNIVERSITY

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Redesign of the Core Curriculum at Duke University

Introduction

The entire undergraduate curriculum of the Electrical and Computer Engineering (ECE) Department in the Pratt School of Engineering at Duke University is undergoing substantive revisions. Our goals are to revise the overall structure of the curriculum while incorporating a theme of Integrated Sensing and Information Processing (ISIP), to provide continuity by emphasizing the interrelatedness of ECE topic areas, and to incorporate innovative pedagogical techniques and hands-on experience throughout the curriculum while maintaining our curricular flexibility. The ISIP theme is compatible with research strengths of our faculty, and the broader themes of biology, economics, and computer science that our students often pursue with their electives. Our focus in the first year of the curriculum reform has been on restructuring and redefining the core curriculum, responding to assessment results, implementing several new assessment tools, and planning and executing two pedagogical workshops. In this paper, we describe the process by which we have modified the core curriculum and the results of the redesign. [This work was supported by NSF grant EEC- 0431812].

Initial assessment activities associated with our legacy curriculum indicated several areas that needed to be strengthened. First, students rarely felt they understood the coherent, overarching framework that integrates basic principles. Second, there was an unbalanced coverage of fundamental areas of ECE. Finally, the laboratory and design elements of the curriculum were not optimally utilized.

We developed a framework for the core which includes 6 classes, the second of which (denoted ECE 27 and titled *Fundamentals of ECE*) is a first-year design experience which introduces students to all aspects of the ECE curriculum. The first course remains the *Computational Methods in Engineering* which was recently redesigned and has achieved outstanding assessment results. The remaining four courses are *Introduction to Microelectronic Devices and Circuits, Signals and Systems, Logic and Computer Architecture,* and *Electromagnetics.* This structure substantially reduces the legacy material focused on circuits and devices, and as described in the paper uses a different pedagogical structure in each of the four core courses. In order to achieve our goals, and to carefully ensure consideration of tradeoffs associated with the redesign, we developed a series of roles to effect the organization necessary for the reform process. The key roles that have been developed and assigned are (1) course leader, (2) theme team, (3) approval team, (4) advisory team, and (5) project manager. In the paper, the roles and responsibilities of each of these groups in the process is also described.

To proceed with the redesign of the core, the course leaders were responsible for developing the course content, syllabus, homeworks, tests, and lab manuals in concert with their course team. Course leaders met separately with their course teams, and then periodically the course leaders, along with the management team, met to assess progress and work out various issues. The *Signals and Systems* and *Electromagnetics* courses have been modified the least in terms of the material covered, but have been dramatically strengthened through the introduction of a hands-on laboratory that is tightly integrated with the course and consistent with the curricular theme. Additional material has also been added since some of the material historically taught in the class has been moved to *Fundamentals of ECE. Logic and Computer Architecture* has been modernized and streamlined, and several new lab activities have been added in conjunction with the curricular theme. The *Introduction to Microelectronic Devices and Circuits* class is dramatically different from the previous two core courses, both in content and in lab. A new textbook is under development for this course since no similar course or texts exists. Similarly, *Fundamentals of ECE* has been developed completely from scratch, and a textbook is also being developed for this class. Details of the redesign of each of the courses, as well as a description of the linkages that now exist between the courses, are provided below.

Restructuring the Core Curriculum

In the old curriculum, each student is required to take a set of seven core courses (six ECE courses plus one programming/numerical methods course). The core courses that are currently required are: *Numerical Methods, Introduction to Electric Circuits, Introduction to Electronics: Devices*, *Signals and Systems*, *Introduction to Switching Theory*, *Introduction to Integrated Circuits*, *Electromagnetics*. Our goal in this effort is to develop a new, innovative curriculum for the ECE department that focuses on ECE fundamentals within the construct of real-world integrated system design, analysis, and problem solving. Specifically, our goal was to rebalance the core curriculum to better represent the three central topics of ECE defined by Lee and Messerschmitt [1]: electronics, information systems, and computer science. This restructuring is similar to that described in [2], but differs in key ways described below.

To proceed, we developed a management structure which consisted of a course leader for each new course. The course leaders were responsible for developing the course content, syllabus, homeworks, tests, and lab manuals in concert with their course team. Course leaders met separately with their course teams, and then periodically the course leaders, along with the management team, met to assess progress and work out various issues.

The *Introduction to Signals and Systems* and *Introduction to Electromagnetics* courses have been modified the least in terms of the material covered, but have been dramatically strengthened through the introduction of a hands-on laboratory that is tightly integrated with the course and consistent with the curricular theme. Additional material has also been added since some of the material historically taught in the class has been moved to *Fundamentals of ECE. Introduction to Logic and Computer Architecture* has been modernized and streamlined, and several new lab activities have been added in conjunction with the curricular theme. The *Introduction to Microelectronic Devices and Circuits* class is dramatically different from the previous two core courses, both in content and in lab. A new textbook is under development for this course since no similar course or texts exists that we are aware of. Similarly, *Fundamentals of ECE* has been developed completely from scratch, and a textbook is also being developed for this class. Details associated with all of these development efforts are provided below, with the most detail provided for those courses that have been created or have been modified the most.

The procedure required to develop each of these courses was sequential. Initially, all current core courses were ‘deconstructed’ by the course leaders and management team, and debate ensued regarding what legacy material could be deleted, and what material should be added. Originally, since the introductory course had not been designed, it was unclear as to what basic material would be presented in ECE 27, and thus what the launching off point was for the new core courses. To address this sequencing problem, the entire group (course leaders and management team) met periodically to update expectations and discuss progress.

Fundamentals of ECE (ECE 27)

In the first year of this grant, one focus has been on the development of a new, theme-based introductory course entitled *Fundamentals of ECE*. One goal of this course is to introduce all major areas of ECE to students in their first year of study. Thus, this course has been organized around four of the central concepts in ECE: 1) how to interface with the physical world, 2) how to transfer/transmit energy/information, 3) how to extract/analyze/interpret information, and 4) how to organize and store information. Other goals include illustrating how various areas of ECE contribute to the design and functioning of an entire system, emphasizing the relevance of course material to real-world applications, and capturing the students' imagination and creativity. These goals will be achieved, in part, through the use of a unifying theme that will provide an overarching framework for study, through a tight coupling between lecture and laboratory exercises, and by developing a laboratory experience that emphasizes design, integration, and real applications.

As the laboratory experience and its integration with the rest of the course is critical to achieving the goals of the course, *Fundamentals of ECE*, the content and organization of the course evolved through an iterative process. The first step in the process required each Core Course Development Team to analyze the current curriculum and to deconstruct existing courses into a list of concepts. Next, these lists were prioritized, with legacy material eliminated and fresh concepts added. At this point, the lists were handed to the *Fundamentals of ECE* Development Team, which consisted of faculty members representing each major area of ECE. After reviewing the concept lists, the team constructed a preliminary course syllabus for the new introductory course.

At the same time, the *Fundamentals of ECE* team investigated possible platforms on which to base the laboratory. The ideal platform would enable the exploration of a broad range of ECE concepts, both independently and integrated into an entire system. The platform must also be flexible, to encourage creative solutions, capable of being applied to real-world challenges, and easily connected to the curricular theme of Integrated Sensing and Information Processing. After exploring several options, the use of a robotic platform rose to the top. Specifically, the team chose to base the laboratory experience on the Parallax BASIC Stamp microcontroller. This particular platform was chosen, in part, because the number and variety of accessories (particularly sensors) is extensive. In addition, it is quite simple to program the microcontroller thereby allowing students to focus on the sensors and system design, rather than having to spend their time programming the robot.

Having selected an appropriate laboratory platform and using the preliminary course syllabus as a guide, the team began developing the overall laboratory structure and individual laboratory exercises. It was decided that the laboratory would be divided into two major modules. The first module, containing 9 week-long laboratory exercises, was designed to introduce students to the individual components making up the robotic system. These components roughly correspond to the four central concepts on which the course is based: information gathering (focusing on how the robot uses sensors to interface with the physical world), information transmission (focusing on how the robot conveys information to a central location), information processing (how useful information is extracted from the data collected by the robot and used to make decisions or control the robot), and networking and information storage (how the robot's data is managed and how multiple robots can be used to achieve a common goal). The second module, referred to as the Integrated Design Challenge, spans the final 5 weeks of the semester and requires students to design, build, and test a robot capable of performing a task (or series of tasks). To be successful, the robot must integrate concepts from each of the four major areas covered in the first laboratory module.

In designing the nine laboratory exercises composing the first laboratory module, the goal was to engage the students in activities that reinforced concepts presented in lecture using real-world applications for motivation. In order to develop both the students' conceptual understanding and their design skills, each laboratory session includes a more structured instructional component, in which basic concepts will be investigated, followed by a more open-ended exploration component, during which students will be challenged to design a robot that completes a real-world task. The relative portion of the laboratory session devoted to each component evolves over time from being primarily instructional, when everything in the laboratory is new to students, to being primarily exploratory, culminating in the Integrated Design Challenge. The nine laboratory exercises in the first module are described in a paper also submitted to ASEE 2006.

Through this series of nine laboratory exercises (the first module), students will be introduced to a variety of sensors (e.g., temperature, pressure, IR pair), learn how to interface these sensors with the physical world in order to gather information, and learn how to store that information for later analysis or use that information to make decisions affecting the behavior of the robot. Each laboratory will focus primarily on one major concept area (e.g., physical devices or information transmission), but, due to the nature of the robotic platform, it is natural that students will see connections between multiple major areas in each project.

The laboratory experience will culminate in the 5-week Integrated Design Challenge. For the Challenge, students (working in groups of two) will be given a series of tasks that their robot must be able to complete. However, a single group will not complete these tasks independently. Rather, multiple groups will be required to cooperate to complete the tasks. For example, a series of three tasks will be assigned and each group must build a robot capable of completing each task. However, when it is time to test the robot, three groups (with three individual robots) will be teamed together and must complete the tasks sequentially, with one robot activating the next upon completion of its assigned task. The group as a whole, as well as individual robots, will be timed. Then, the task assignments will rotate and the process will be repeated until each robot has completed each task. In addition to technical concepts, student will learn skills related to project and team management, whole-system integration, budgeting, and technical communication.

As the laboratory exercises were being designed, team members referred to and modified the original course syllabus. Given the integrated approach to teaching ECE concepts, it was clear that the course could not be taught by sequentially introducing circuits and devices, followed by signal processing, electromagnetics, and digital logic. In other words, the syllabus could not be determined by simply lifting a quarter of the syllabi of existing core courses and appending them to each other. Rather, the final syllabus for *Fundamentals of ECE* introduces concepts in a very integrated manner, reflecting the approach taken in the laboratory. This organization, which is unlike traditional courses, is critical to the success of the course as it emphasizes the interrelationships between major ECE areas and embodies the curricular theme.

In the next year of this project, *Fundamentals of ECE* will proceed through the process of being approved by the faculty and is being piloted currently in the Spring of 2006. This offering of the course will be limited to 20 students. New teaching methods, such as think-pair-share and minute papers, to which the faculty have been exposed through bi-annual teaching workshops offered in conjunction with this grant, will be used to enhance the learning experience.

Introduction to Microelectronic Devices and Circuits (ECE 5)

ECE 51 is intended to be a vertically integrated introduction to microelectronic devices and sensors, and their circuits. This goal will be achieved by emphasizing a hands-on knowledge of the analysis, simulation, design, and characterization of devices and circuits.

ECE 51 will be focused on a project-based laboratory. The laboratory will be the driving force in the course. In other words, the classroom lectures will be in the form of answers raised in the course of working on the project. To this end, the grading in ECE 51 will be mainly based on the performance of ECE 51 students in the laboratory (laboratory notebook, project presentations, etc ...).

There will be an emphasis on the link between device and sensor properties and design on one hand and circuit performance on the other hand. A student enrolled in ECE 51 as the one-and-only class that deals with devices and circuits will be equipped with the working skills needed to analyze and design circuits. A student taking this core class and experiencing the entire process ending with circuit analysis, design, and testing, will become motivated to take subsequent classes rather than waiting until much later on in their undergraduate experience.

The approach in ECE 51 is to introduce students to microelectronic devices and sensors and the focus will be on developing the relationship between the device structure/operation and the electrical components of their equivalent circuit. This equivalent circuit is used in circuit simulations to analyze and predict the circuit performance of basic analog and digital circuits. The device equivalent models encountered in ECE 51 will be elementary. This point will be made clear to the students in this class. For example, even though MOS devices and circuits will be based on the basic level-2 SPICE model, it will be made clear that BSIM4 and BSIM5 models are the state of the art. A general list of lecture topics with the number of lectures assigned to each is shown below. Following this general list, a more specific list of topics and sub-topics is provided.

List of Lecture Topics (No. of 75 min lectures)

Introduction/Vertical Integration	(2)
Semiconductor Properties	(1)
Semiconductor Device Physics	(1)
PN-Junction Diodes	(2)
MOS Capacitors	(2)
MOS Transistors	(2)
Solid-State Sensors	(2)
Static Circuit Analysis	(1)
Dynamic Circuit Analysis	(1)
Analog Circuits	(2)
Logic Circuits	(2)
Memory Circuits	(2)
A/D and D/A Circuits	(1)
Sensor Circuits	(2)

Based on this course design, the following are the list of topics that must be covered rigorously in ECE 27 (1) Passive circuits elements (R, C, and L); (2) Definition of the applied voltage across an element (and its polarity), the current flowing through it (and its direction), and the power dissipated in it (or generated by it); (3) Circuit analysis principles covering Kirchhoff's laws only.

The ECE 51 Laboratory will be carried out in two phases with the final goal the design and test of an alarm/clock/temperature testing system. Components from the BOEBOT exercises will be used whenever possible. Components of the system include: Manual means for setting the time; Manual means for setting the alarm; Manual means for pushing the alarm-off or snooze button.; Oscillator circuit to keep time; Control circuits to activate the alarm; Control circuits to indicate AM/PM; Temperature sensing system (thermocouple, A/D, temperature display); Display system to display time, alarm time, and temperature.

The first phase of the lab builds on the experience of ECE 27, and consists of a basic laboratory orientation and stresses fundamental measurements and measurement processes. Labs in the first phase include: General introduction to the electrical characterization of electronic devices and circuits; Element and Device characterization and parameter extraction; Sensor characterization and parameter extraction; Analog-circuit characterization; Digital-circuit characterization.

At the end of the first phase, ECE 51 students will have designed and simulated a basic design for their project, and will be ready to enter Phase 2 in which they will perform specific design, construction and testing laboratories associated with their specific project. Labs include: Project design, construction, and debugging; Project circuit testing and characterization. (static circuits, dynamic circuits, display circuits, sensing circuits, audio circuits); Project circuit simulation.

Introduction to Logic and Computer Architecture (ECE 52)

ECE 52, our new introduction to digital logic and computer engineering course, has been designed and offered once in prototype form in spring 2005 under the guise of its predecessor course, ECE 151 (Intro to Switching Theory), and will be iteratively refined again this spring

(2006) prior to its first official offering in the AY06/07. Though ECE 52 takes the old switching theory course as its starting point, it compresses the traditional (overly) thorough treatments of classical combinational and sequential design by concentrating on basics and stressing use of good CAD tools and structured iterative design techniques to implement more complex, realistic systems. Some of this acceleration was accomplished by preparing a complete set of computer-projected slides for all 42 lectures and making these available to the students. This is material which, if presented in a chalkboard or whiteboard environment, requires significant amounts of time drawing detailed but straightforward (and error prone!) tables, circuit diagrams, etc. – an example is 4 and 5 variable Karnaugh maps. These accelerations make room for a much expanded treatment of VHDL, addition of a basic computer architecture unit, and the re-introduction of asynchronous design considerations that have been missing from the course for a number of years. Specifically, elements of ECE 152 (Introduction to Computer Architecture), ECE 154 (Introduction to Embedded Systems), and ECE 251 (Advanced Digital System Design) have been brought down into the introductory course. ECE 52 assumes that power consumption, Ohm's law and Kirchoff's laws are covered in ECE 27.

Additionally, the predecessor course was cross-listed with our computer science department, so it had been a course objective to abstract away as many details of realistic hardware behavior as possible, as the computer science students had no preparation in circuits and systems. That philosophy has been reversed, so that realistic circuit constraints (such as power consumption considerations) are introduced early, and details of devices, circuits, and interfacing techniques are presented throughout the course. This permits the course to tie back much more closely with the curricular theme of integrated sensing and processing, as students see from their earliest labs the utility of custom logic circuits for processing inputs from external sensors (mostly binary switches in this course, ADCs in follow-on courses) to produce and display (typically on LEDs in this course) relevant results.

Except for the first introductory lab, the laboratories associated with the course were completely redone to link the lab material tightly with the lecture material, so that students could use lab time to reinforce and develop practical familiarity with techniques taught rapidly in lecture. The labs stress use of simulation in our CAD environment prior to building actual hardware, be it individual gates or some kind of PLD. The use of VHDL to implement practical circuits of increasing complexity over the course of the semester was stressed. Many of the labs require students to measure practical performance details of their circuits. The mysterious "gray boxes" that had abstracted away all of the details of switch and LED interfacing were replaced with exposed interfacing circuits.

Finally, and most significantly, a major design project was added for the last month of the course, largely in lab time, to connect back to the Integrated Sensing and Processing theme, so that students were able to design in VHDL realistic sequential systems involving multiple sensors and actuators, and implement these designs on FPGAs or other PLDs plus appropriate interfacing components. These projects completed largely by freshmen and sophomores were of comparable complexity and quality (though admittedly lacking in documentation quality) to those produced by the seniors in our ABET design course for digital systems. Projects in the first prototype offering included realistic vending machine controllers (making change, handling empty items, etc.), traffic light controllers for complex intersections (left turn signals only when needed, inputs for green-overrides from emergency vehicles, etc.), and some custom-designed electronic games.

Introduction to Electromagnetics (ECE 53)

The new ECE 53 is based closely on the current junior/senior level electromagnetics course, ECE170L (Electromagnetic Fields). The material in 53 is less dependent on prior ECE courses than others undergoing revision, and the revision plan described here modifies the fundamental content of the course less than those in other 5X courses. However, this course has not had a true laboratory component in the past, and significant effort has been expended in developing a new lab component. Moreover, in order to improve the course and meet the constraints of the new undergraduate curriculum, numerous changes have been implemented in the updated course material. These changes are described below.

In order to adhere to the sensing and processing theme and to better reflect modern applications of electromagnetics, the subjects covered in ECE 53 have been revised, as reflected in the new syllabus and course material. The new course roughly follows the previous one for the first 75% of the course: transmission lines, electro- and magnetostatics, electromagnetic wave fundamentals, and reflection/transmission at interfaces. However, modifications have been made to this existing material to integrate the sensing and processing theme, as described below. The remaining material in the course historically has varied from instructor to instructor and included subjects such as waveguides. In the new course plan, the section on statics has been compressed in order to create space for new material on antennas and communication links that will be covered by all instructors. This compression is justified because, ideally, the students have had solid exposure to electrostatics and magnetostatics from their undergraduate physics courses (which have also been recently revised). In the past each instructor has used a different textbook when teaching this course: the aim is to now have everyone teach from the same text (Ulaby, Fundamentals of Applied Electromagnetics).

Of all material covered in undergraduate electromagnetics courses, antennas and communication links are most closely tied to the sensing and processing theme through the notion of wireless transmission of data. With this in mind, the new course uses antennas as the common thread woven throughout the entire course that is linked to the theme. Antennas are used as a realistic prototypical example of a transmission line load throughout that portion of the course. The inherent capacitance and inductance of electrically small antennas is discussed in depth during the statics portion of the course. And, antennas and wireless transmission become the focus of the course in the last two weeks after plane wave propagation has been introduced. This antenna theme is also woven into the new laboratory element as described below. ECE 53 assumes that RLC circuits, phasors, and power computations are covered in ECE 27.

The current ECE 170L has not had any laboratory for many years; instead, the official “lab” element of the course has been a recitation section. Consequently, the lab development began from scratch and is where the majority of effort went in the updating of this course. The recitation section has been successful over the years because the students benefit from additional explanation and discussion regarding the fairly mathematical and perceived-as-challenging material in electromagnetics. But the benefits of having some laboratory elements to provide some tangible, physical connection to the material are clear, as well as necessary to meet the goals of the new curriculum. The new version of the course alternates between recitation sessions and laboratories, with 5 labs across the semester. The new laboratories cover 5 primary elements of the course: 1) transmission line transients, 2) transmission line sinusoidal steady state and impedance matching, 3) electrostatics and magnetostatics including capacitance and inductance, 4) electromagnetic waves, and 5) antennas and wireless links. Labs 1, 2, and 5 are hardware-based. Lab 3 is simulation-based and uses modern design tools (Ansoft HFSS and Comsol FEMLAB) to design an on-chip inductor and to compute the capacitance of a dipole antenna. Lab 4 is also simulation-based and uses FEMLAB to simulate wave propagation and transmission/reflection at multiple interfaces in order to give the students visual insight into these processes.

By dividing the non-lecture time between lab and recitation, we more easily ensure that the lab and lecture material are synchronized so that the students have had the material in lecture before dealing with it in the lab. In other words, the class and lab are not racing through material in order to keep up with each other. The labs are designed to connect in some way to the sensing and processing theme as well as possible using the overarching antenna connection between electromagnetics and the theme. Lab 2 requires that students measure the impedance of a small dipole antenna using slotted transmission line techniques, while Labs 3 and 5 are focused partly on antenna design and antenna application elements, respectively. The final, antenna and communication link laboratory has the strongest connection and will thereby provide a finish to the course that effectively ties together the course (electromagnetics) and the theme (sensing and processing).

Introduction to Signals and Systems (ECE 54)

The development of the new *Signals and Systems* core course, ECE 54, has leveraged ongoing efforts (supported by NSF CCLI grant DUE-0410596) to introduce hands-on laboratory exercises into core and elective signal processing courses. The curriculum revision and laboratory development efforts are complementary because the cornerstone of the new curriculum, *"Fundamentals of ECE"*, now introduces students to basic signal processing concepts, thereby enabling the topical coverage of the revised Signals & Systems core course (ECE 54) to be expanded to include more in-depth coverage of discrete-time signals. Furthermore, the addition of a formal laboratory period will allow some new topics to be added that previously have proven difficult to cover and explore in a purely classroom-oriented course – for example, voice scrambling. Finally, the course will exploit the release of Wiley's new JustAsk! feature for the current textbook. This educational supplement includes interactive tutorials and demonstrations that students can use outside of class to strengthen their knowledge of key concepts and practice their problem solving techniques. Having these supplements available will reduce the amount of in-time class spent going over examples, since students will now be able to go to their computers or public clusters and run through the tutorials themselves. Some of these tutorials will also be used in the classroom and in the laboratory, particularly at the beginning of the course in order to help familiarize the students with the tools.

The additional topical coverage in the lectures and in students' reading, in turn, provides the foundation needed for students to explore signal processing concepts and applications through

DSP hardware-based exercises in the laboratory. The specific DSP platform (the Texas Instruments C6713 board) was selected because it can be easily interfaced with MATLAB and SIMULINK, minimizing programming time and allowing students to focus on algorithm design and implementation. In addition, the use of MATLAB is in keeping with the goal of the curriculum revision to have this software tool integrated throughout the new curriculum. Four laboratory projects have been developed and are being piloted in the Fall 2005 semester. They are briefly described below. ECE 54 assumes that the concept of frequency space, Ohm's Law, Kirchhoff's Laws and solution methods based on Kirchhoff's Laws, instrumentation techniques, and PBASIC/BOEBOT basics (system interaction, integration, and control) are covered in ECE 27.

Laboratory #1: Digital Audio Effects In the first project, students will investigate the concepts of signal manipulation by exploring simple digital audio effects (e.g., echo, flange, and reverberation). The mathematical manipulations discussed in class will be implemented in real-time and used to process signals such as the student's voice (via microphone input) or digital music files. The use of audio signals will provide a link between the mathematical manipulations (theory) and the physical realizations (perception).

Laboratory #2: Touch-Tone Phone In a second project, students will design and implement a dual-tone multi-frequency (DTMF) encoder/decoder. An example of a DTMF system is a touch-tone phone: when any key on the telephone key pad is pressed, a pair of sinusoids are generated and added together, producing a "dual tone." Background information that describes the principles behind DTMF and the touch-tone phone system application will be provided, both to motivate the students and to provide the parameters and constraints with which they have to work.

Laboratory #3: Voice Scrambler / Descrambler The third project is designed to illustrate the basic principles of modulation and demodulation. The laboratory exercise will include shifting the spectrum of a speech signal in real-time (using the principle of modulation) such that the message is "scrambled" and unrecognizable. Students will then transmit the scrambled signal to a second system which will operate as a descrambler.

Laboratory #4: Sampling & Aliasing In this project, students will investigate the effects of aliasing that can arise when digitally processing a continuous-time signal. They will make theoretical, visual, and aural observations that illustrate these effects and demonstrate how an anti-aliasing filter can be used to avoid or minimize these unwanted effects. A real-world application, such as the public telephone system, will be described to provided context and system design parameters.

When the transition is made from ECE 64 to ECE 54, new laboratories will be added to integrate the Parallax Basic Stamp 2 microcontroller and the BOEBOT robotics kit. The additional material in these laboratories will exploit the knowledge gained in the ECE 27 course and integrate the theme of integrated systems and signal processing. The goal will be to take fundamental concepts of signals and systems learned in ECE 27, expand and deepen that knowledge in the ECE 54 lectures, then explore concrete examples through the laboratories in ECE 54 while continuing to use the microcontroller-based robot. Specific laboratories will include:

Laboratory R1: Tone Recognition In this project, student will use a basic RLC filter in concert with an omnidirectional microphone to have their robot seek out a particular tone in a room with two or more single-frequency sources. The student will need to design a filter that has a wide enough bandwidth to account for the tolerance of the passive components they are using while narrow enough not to "find" other frequencies in the room. They will then attach this to their robot and write a "search and destroy" algorithm based on the inputs from the microphone.

Laboratory R2: Secret Messages In this project, students will use an image processing system and correlation to identify a "secret message" and then use a frequency-based scrambling system to encode the message and communicate it to another team of students. That team will need to decode the message, which in turn will motivate their robot to complete a particular task. This lab will integrate the Bluetooth communications protocol and robotics skills learned from ECE 27 with the signal processing and frequency analysis of ECE 54.

When completed, the transition from the ECE 64 course to the ECE 54 course will mark a fundamental shift in the way linear system theory is taught. The focus will now be on integrated systems and signal processing within the context of real-world devices. Students' learning of the material will be truly vertically integrated in a way that draws on their experiences in the ECE27: Fundamentals of ECE and EGR53: Computational Methods in Engineering Courses. The new formal laboratories will continue this integration by giving the students an opportunity to expand their knowledge of microcontrollers and robots through directed laboratory experiments.

Pedagogical Techniques and Alternative Learning Experiences

As we develop new classes, we have the opportunity to significantly update our pedagogical techniques. Each semester we offer learning opportunities for our faculty. In the fall of 2004, we had a one-day workshop on engineering pedagogy (Felder/Brent) and during the spring semester 2005, we held an internal teaching roundtable discussion. We are also working with experts in the scholarship of learning to integrate critical thinking skills into our introductory ECE 27 course. During the next year two workshops have been planned. The first, which is partially in response to recent assessment results, focuses on advising and retention. The second focuses on using technology in the classroom.

With our curriculum revision, we believe we are creating learning experiences that will be defining for ECE education across the nation. To build on this core, we are considering and creating additional student-faculty experiences that aim to 1) enhance the personal development of students; 2) engage students and faculty together in consideration of the world's greatest opportunities and challenges; 3) provide new means of thinking with the conscious consideration of learning and creativity through art and design. In addition, these activities will build a sense of community in ECE, significantly enhance the differentiation of our ECE program from others; and will strongly leverage Duke's strengths overall. Our plan also includes making the following experiences, or a subset, required of ECE students:

Year 1: Engineering and Art: An Integrated Learning Experience. The goal of this experience is to educate students on the current knowledge about creativity, learning and design through integrated art and engineering projects.

Year 2: Leadership: Developing Personal Potential. Leadership develops over time and cannot be explicitly taught. That said, leadership can be enhanced through the conscious consideration of great leaders and the tools that enhance their effectiveness. In partnership with Fuqua and the MEM program in Pratt, we will create a Leadership Institute that all of our students will participate in.

Year 3: Global Issues: Opportunities and Challenges. Great issues face us today. Students and faculty will be engaged (over a meal) together- on a monthly basis- with Duke leaders to discuss these issues. This activity could be coupled to international summer opportunities after the junior year.

Year 4: Leadership Revisited. The Leadership Institute is revisited and enhanced during the senior year.

Assessment

There were three activities associated with our assessment activities this year: response to prior assessment activities, modification of internal assessment procedures, and continuation of external assessment activities. Each of these will be reviewed below.

Responses to Prior Assessment Results

One of the critical departmental issues highlighted during the planning phase of this effort (supported by a planning grant from NSF, EEC-0343168) was the lack of a strong lab component throughout the curriculum. Several strides have been made this year to address those criticisms. In 2005, the position of Undergraduate Laboratory Manager was added to the Department. The Lab Manager ensures the connection between lecture content and laboratory experiments in an effort to enhance the overall undergraduate educational experience. The ECE Department hired a lab manager, reporting to the Department's Director of Undergraduate Laboratories (DUL). In addition, as detailed below, the structure of, training of, and assessment of teaching assistants has been completely overhauled.

Teaching assistants are assigned to courses in the Department based upon instructor nomination, self-interest, and field of study. In the case of undergraduate TAs, careful consideration of past performance, ability to instruct students, and interest in the subject are weighed together to identify the very best pool of candidates. Graduate TAs are typically placed in upper-level ECE courses in accordance with their particular field of study to ensure a match between their interests and research and course needs. All teaching assistants are required to meet with the Undergraduate Laboratory Manager and, in the case of homework grader and recitation TAs, the course instructor as well, to gain a complete understanding of their responsibilities and job expectations. Laboratory Teaching Assistants attend a Departmental orientation which includes overall laboratory procedures in ECE as well as safe lab practices. Since the best way to prepare for labs is to conduct the experiment oneself using the students' lab manual, each group of course TAs in a laboratory section attends a weekly lab preparatory meeting in which the lab is conducted. This allows students teaching the course to re-gain familiarity with the material as well as address common pitfalls in anticipation of teaching students in the lab the following week. Motivating introductions are required in each lab section in order to help place lecture material into context with laboratory experiments. Consistent grading of laboratory reports and general improvement of lab instruction is also ensured through weekly meetings and contacts with Teaching Assistants. Anonymous student assessment of laboratory courses and Teaching Assistants is performed electronically on-line on a semesterly basis in order to provide instructors and TAs with feedback on course improvements and overall performance.

Internal Assessment Activities

Currently, we have revisited and restructured our assessment process. We have both an internal activity and an external activity. First, modifications to the internal activity associated with teaching evaluations are described. In the past, written evaluation forms were available to the individual faculty, Director of Undergraduate Studies (DUS), and Chair. Course and Instructor averages were tabulated by hand and reported on the individual faculty's Scholarly Activity Reports. Historically, the DUS reviewed all teaching evaluations for all undergraduate courses, presented summarized information to the Chair, and made recommendations to the Chair regarding issues and proposed actions.

Given the recent changes in teaching assessment procedures, including new, scannable forms and additional lab evaluation forms, the sheer volume of information available to the chair and DUS has increased dramatically. With the advent of the new scannable forms, significantly more data can be tabulated and reported. Trends can be tracked in terms of course, instructor, semester, etc. Also, statistical analyses of the data (e.g. correlation between grade and course evaluation) can be tracked quite easily. General trends can be reported to the faculty at large, as can information regarding statistics associated with course averages, instructor averages, and mean grades.

The UGSC was asked by the Chair and the DUS to consider detailed mechanisms by which a more comprehensive review process could be implemented. Specifically, given the increasing numbers of faculty and courses being offered, and the transition to a new undergraduate curriculum, the UGSC was asked to develop a plan to help monitor UG course evaluations and teaching assignments. The UGSC recommended that all of the quantitative information available about all courses with substantive undergraduate enrollment be made available to the UGSC each semester. None of the written comments from the students will be made available to the UGSC. Along with the information associated with a given semester, historical information will also be made available in order to provide context. Supplemental information, including average grade for a course, and summary statistics for the undergraduate courses as a whole (averages for each question, average grades, etc.) will also be made available to the UGSC. Additional information including EBI surveys, department-initiated surveys and focus groups, and departmental statistics (e.g. numbers of majors, double majors, numbers of students in the various tracks, teaching load by track, etc.) will also be considered.

Each semester, the UGSC will analyze the data associated with the current semester within the context of the historical data, and will report their findings to the DUS. The DUS can then provide the report from the UGSC, in addition to any other relevant information, to the Chair, along with recommendations regarding issues and proposed actions that arise from the DUS. The goal of the proposed action is to provide an additional layer of assessment of the undergraduate teaching activity, to help process the volumes of data that are currently being analyzed solely by the DUS, and to help ensure that the system of checks and balances and the feedback loop is working effectively. A yearly report will also be provided to the faculty. This approach was first implemented in the Fall of 2005 and was well received by the faculty.

External Assessment Activities

In addition to these modifications to our internal assessment, our external consultant (AcuityEdge Inc.) conducted a senior exit survey, a series of in depth interviews, and a focus group with seniors. Results of these activities are summarized below. In addition, the consumer interviews activity was designed and executed in the fall of 2005. In this activity, individuals at the primary industrial and academic destinations of our undergraduates were interviewed to assess their perception of the strengths and weaknesses of Duke ECE undergraduates. This process is still ongoing, but one of the key outcomes has been a mirroring of the students' perception that they are strong on theory but weak on practice. The redesign of the core courses should help alleviate this issue.

The survey/interview/focus group process was performed in April of 2005 as the most recent group of seniors graduated. Most had still not felt the impact of the changes in the lab structure described above, as most were participating in their senior design activities as their only lab experience. Several had been through a new design course, however, that was developed with the new curricular theme in mind and which is taught using modern pedagogical techniques. AcuityEdge summarized the results in a briefing provided to the executive team, and this briefing will also be presented to the faculty at a faculty meeting. Survey, interview, and focus group outcomes were self consistent.

Categories of questions and topics covered in the assessment effort were core courses, curriculum and instruction, materials and resources, interactivity, and overall education experience. In terms of the core courses, feedback suggests that the students perceive the instruction in the majority of the core courses to be excellent, but are quite disappointed in their lab experiences and in the disconnected nature of the material in the courses. These are both issues that are being addressed in the redesign of the core curriculum. In fact, preliminary internal assessment efforts of the new lab structure imposed since hiring the lab manager suggests that student perception of the TA training (a major source of concern expressed in the focus group) is dramatically improving.

In terms of overall curriculum and instruction, students are generally satisfied with electives and design courses. They were dissatisfied with the depth within sequences, course integration and linkages across courses, and experiences with labs. Again, proposed modifications to the curriculum within the curriculum reform process address each of these issues, and will be a key component of the activities in year 2. In terms of input on materials and resources, students again were generally satisfied, with the exception of their perception of the laboratory facilities.

One key issue that arose this year, and which was also observed in the EBI survey, arose when students were questioned about their assessment of interactivity in their educational experience. Students were quite happy with their student-student interactions and their student-instructor interactions, but were quite unhappy with their student-advisor interactions. Several students in the focus group noted that student interests and advisor interests are not aligned when assigning advisors to advisees. They also noted that there are some notoriously good and notoriously bad advisors. The ECE Department, and the Pratt School of Engineering as a whole, are considering alternatives to the current advising process.

In terms of their overall learning experience, students felt that a strength of the program was the skills they developed for problem solving and theory. Weaknesses that the students noted included a lack of exposure to non-technical topics, a lack of exposure to cutting-edge topics, and a relatively limited exposure to hands-on design. The yearly programs designed above should address the first of these issues to some extent, and curricular reform efforts are aimed at addressing the latter.

Conclusions

We have begun an extensive ECE curriculum redesign. Our initial assessment results allowed us to pinpoint opportunities for improvement and brainstorm strategies for this improvement. We have created a streamlined course structure, which is consistent with an educational theme and have developed and begun to pilot the new core courses. To support our activities, we have developed a curriculum design process that incorporates an extended support structure for management of the reform process. Assessment of the first phase, redesign of the core, should be completed by the end of the fall semester, 2006, and we expect to matriculate our first students in the Fall of 2007. This effort has been supported to date by an NSF grant totally nearly $1M. In the out years, we have budgeted needed lab activities and expect to be able to continue to support the effort with a budget of $25K/year. The second phase of this process, redesign of the upper level technical electives, is on schedule to be completed by the end of the fall semester, 2006.

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