DLR: Improving the Quality and Student Appeal of Undergraduate Electrical Engineering Education

A  Project Summary

Electrical Engineering, a core engineering field with a reputation for leading to high-income jobs, has historically been a popular major at the University of Virginia (UVA) and across the country. The silicon and information technology booms of the past few decades have added dramatically to the prestige and prosperity of the field, resulting in increased opportunities for employment and personal enrichment. At the same time, student interest in Electrical Engineering has waned of late, not only at UVA but in engineering schools across the country. Total enrollment has declined, and Electrical Engineering is losing many of the brightest and underrepresented students to other majors.

Some cynically explain this trend by claiming that the current generation of students is simply unwilling to put forth the large amount of effort for which undergraduate Electrical Engineering programs have a reputation. In reality, most students actually want to be challenged, but they need motivation to push themselves to achieve their highest potential. It is therefore the educator’s responsibility to not only disseminate a curriculum’s material but to create an air of enthusiasm, practicality, and accessibility surrounding that material. Much of this can be done by putting the curriculum into a context to which the students can relate and making their educational experience more relevant to engineering practice. Surveys of our own Electrical Engineering graduates reveal these shortcomings in our program, and these were students who chose and completed the program. It is these same shortcomings that likely hurt our ability to attract and retain other students.

This proposal details a planning project to address this problem at UVA and put the Charles L. Brown Department of Electrical and Computer Engineering in a position to: 1) make the Electrical Engineering undergraduate program more appealing to top and underrepresented students, thus increasing student attraction, retention, and satisfaction (both while in the program and in the years following graduation), and 2) provide students a better overall educational experience both inside and outside the classroom, thus better preparing students for Electrical Engineering practice and increasing the number of program graduates who go on become leaders in their field.

To accomplish these objectives and achieve these outcomes, we address the shortcomings discussed above by exploring the feasibility and assessing the impact of: 1) a curriculum-spanning design project that provides prospective and current students with a “big picture” of Electrical Engineering, putting individual topics in the context of a relatable problem, 2) restructuring the introductory Electrical Engineering courses to better integrate theory and practice, allowing younger students to explore exciting applications of the challenging (and heavily mathematical) theoretical groundwork earlier in the curriculum, and 3) a set of student enrichment opportunities that addresses the diverse interests of our students and better prepares them for leadership roles, including expanded undergraduate research opportunities, undergraduate teaching fellowships, arranged internships, increased interaction with the Business and Law Schools, and curriculum-tracking overseas studies programs. The results of this project will then be disseminated to Electrical Engineering programs at other universities, as programs must work together to ensure the global health of the Electrical Engineering profession.

Intellectual Merit

The primary intellectual contributions of this planning project are twofold. First, we will develop a set of candidate “big picture” design projects and a plan for implementing them throughout the Electrical Engineering undergraduate curriculum. Second, we will implement and assess a novel restructuring of introductory Electrical Engineering courses that exposes students to engineering applications normally reserved for more advanced students. These efforts will be supported by modern pedagogical theory and discussions with those undertaking similar efforts at other universities.

Broader Impacts

When disseminated through publication and educational conferences, these techniques will not only improve the quality and student appeal of undergraduate Electrical Engineering education at UVA, but other universities can apply the techniques to improve programs across the country. Such changes will help attract the brightest and underrepresented students to Electrical Engineering.
C Project Description

The University of Virginia (UVA) Charles L. Brown Department of Electrical and Computer Engineering (ECE) faces considerable challenges and significant opportunities with its undergraduate Electrical Engineering program. Enrollment and overall student satisfaction are declining, but the department’s faculty and core student group are enthusiastic and committed. Led by department chair Lloyd Harriott, the entire ECE faculty will work towards identifying approaches for making Electrical Engineering a more attractive and satisfying program for UVA undergraduate students while increasing the quality of education and student enrichment.

In this proposal, we outline the problems we currently face and our plans for improvement, placed in the context of our past and ongoing challenges and efforts, and modern pedagogical theory and practice. By the end of the proposed work period, we will have established an implementation plan for department-level reform of our Electrical Engineering undergraduate program, culled from careful planning and assessment of the concepts laid out in this proposal.

C.1 Objectives, Outcomes, and Reforms

The objectives and associated desired outcomes of the proposed planning project are to put the department in a position to:

• Make the Electrical Engineering undergraduate program more appealing to top and underrepresented students, thus increasing student attraction, retention, and satisfaction (both while in the program and in the years following graduation).

• Provide students a better overall educational experience both inside and outside the classroom, thus better preparing students for Electrical Engineering practice and increasing the number of program graduates who go on become leaders in their field.

Towards achieving these objectives, we will explore the feasibility and assess the impact of the following reforms:

• A curriculum-spanning design project that provides prospective and current students with a “big picture” of Electrical Engineering, putting individual topics in the context of a relatable problem.

• Restructuring the introductory Electrical Engineering courses to better integrate theory and practice, allowing younger students to explore exciting applications of the challenging (and heavily mathematical) theoretical groundwork earlier in the curriculum.

• A set of student enrichment opportunities that addresses the diverse interests of our students and better prepares them for leadership roles, including expanded undergraduate research opportunities, undergraduate teaching fellowships, arranged internships, increased interaction with the Business and Law Schools, and curriculum-tracking overseas studies programs.

C.2 Background and Current Status

The University of Virginia has one of the oldest electrical engineering degree programs in the United States, having existed for over one hundred years. The Department currently has twenty tenured or tenure-track faculty that both teach and conduct externally-funded research and an additional six research faculty who are focused primarily on performing research and working with graduate students. The undergraduate electrical engineering program supports 162 students.
(years 2 through 4) and a graduate population of 104, the largest graduate program in the School of Engineering and Applied Science (SEAS).

To better understand the general context in which the program finds itself, a few facts about the University and School are in order. UVA is primarily a liberal arts university with engineering, architecture, sciences, medicine, law, and both undergraduate and graduate business. Its residential enrollment is approximately 19,000. The School of Engineering and Applied Science has 141 faculty, an undergraduate population of 1954 students (all four years), and a graduate population of 629. It has nine departments and ten undergraduate degree programs. The School has an excellent reputation and has always controlled its enrollment numbers in order to maintain an excellent student/faculty ratio.

In this section, we detail some of the key issues we currently face that will be addressed by the proposed work. We also discuss our prior department-level efforts to improve the Electrical Engineering program as well as relevant results from prior NSF support.

C.2.1 Enrollment

Historically, Electrical Engineering has been a popular major at UVA and across the country. As a core engineering field and having a reputation for leading to high-income jobs, the B.S.E.E. has long been a sought after degree. The silicon and information technology booms of the past few decades have added dramatically to the prestige and prosperity of the field.

However, like at a number of engineering schools around the country, student interest in Electrical Engineering at UVA has waned, resulting in both decreased total enrollment and the loss of top students to other majors. From the period of 1990 through 1995, the annual enrollment decreased from a high of 80 new students to a low of 50 students. With only a concentration in Computer Engineering within the Electrical Engineering program, the program again grew from 1995 through 2000 to return to the high of approximately 80 students. In 2000, the enrollment of new electrical engineering majors fell to an all time low of 25 students. The enrollment numbers grew during the subsequent years due to some aggressive recruiting but again plummeted back to 25 in the fall of 2003.

There are a variety of arguments about why this decrease in student interest occurred and continues to occur, ranging from increased competition from emerging fields to the new generation of students being unwilling to put forth the large amount of effort for which undergraduate Electrical Engineering programs have a reputation. In truth, it is a mixture of these and other factors, some of which we can do nothing about but most of which we can and do address in this proposal.

Certainly, fields such as Computer Science, Computer Engineering, and Biomedical Engineering are attracting many students who would have been drawn to Electrical Engineering. In fact, Computer Engineering and Biomedical Engineering have only recently been established as undergraduate programs at UVA (in 2000 and 2003, respectively), and the dramatic recent decline in Electrical Engineering declarations can be partially attributed to the popularity of these new programs. For example, after the first year of the existence of the Biomedical Engineering undergraduate program, the program had 50 majors.
Informal student polls have revealed that many undergraduate students are turned off by Electrical Engineering’s reputation for being difficult. This is not something that new students are predisposed to thinking, but rather something that they hear from their peers during their first months at UVA. In fact, a great many engineering students indicate a high level of interest in Electrical Engineering as a major when they first arrive at UVA, but these numbers drop dramatically by the time students declare a major late in their first year. However, our more in-depth investigations into this issue have revealed that students are not afraid of the challenge but rather they have heard of dissatisfaction from Electrical Engineering students, particularly with respect to the introductory courses and the perceived irrelevance and inapplicability of much of the theory-based curriculum.

Such feedback has forced our program to point the finger away from the students and back at ourselves. In order to increase student enrollment, we need not make the curriculum “easier”, but rather make it more relevant and attractive to students by better motivating the material and placing it in a relatable context.

C.2.2 Underrepresented Students

While Electrical Engineering has historically been a popular program, it has always had problems attracting women and minorities. Based on the 2003-04 statistics, only ten percent of the Electrical Engineering majors were women with a School statistic of 25 percent. We are fortunate to have a large percentage of African-American students (eighteen percent) with a School percentage of only seven percent.

A significant amount of research has been done over the past decades to study and address this problem. Some success has been achieved by encouraging increased female and minority participation in science and mathematics at an early age, but we as a program and the field of Electrical Engineering in general are far from achieving the appropriate balance. Recent pedagogical research has revealed other techniques that may help shift the balance [Frye97]. For example, a project-oriented curriculum and hands-on learning have been shown to better attract and retain female and minority engineers. We will explore both as part of the proposed work, as well as additional student enrichment opportunities.

In addition, all efforts to reach rural and inner-city high school students are currently handled at the School and University level, and little effort is made to expose engineering opportunities at UVA to community college students. We will explore organizing department-level outreach activities to promote Electrical Engineering to students who currently receive little exposure to any engineering discipline.

C.2.3 The UVA Engineer

At UVA, we are blessed with some of the most outstanding students in the country. The average combined SAT score for the entering class of 2003-04 was 1348 (704 math and 644 verbal) with more than ten percent of the class with a total SAT score over 1500. Admissions at UVA is highly competitive, and our recent ascendance to the top of the U.S. News and World Report list of best public universities in the country will undoubtedly make it even more so. In addition, UVA tends to attract especially well-rounded engineers. UVA is world renowned for their liberal
arts programs, and most of our engineering students cite access to these programs as a primary reason for coming to UVA instead of choosing more technically oriented universities. In fact, a great many undergraduate engineering students pursue minor degrees in non-technical fields, including Economics, History, and English. Forty percent of the graduating class of 2003 was able to complete a second major or a minor and ten percent completed a second major or minor in economics. As a result, our students are extremely articulate, which employers often note as a primary reason for hiring UVA engineers. In addition, many of our graduates go on to graduate or professional programs in business, law, or medicine as well as engineering. Our vision for the “UVA Engineer” is that of a leader, not only in technical innovation but in industrial management, engineering education, business development, technology law and policy, etc.

Therefore, neither the students nor the faculty are satisfied with a purely technical curriculum. We must identify and make accessible to students opportunities for enrichment beyond the traditional engineering curriculum. While this should be a goal of engineering programs across the country, it is especially vital at UVA. Therefore, as part of the proposed work, we will identify student enrichment opportunities that will make our Electrical Engineering program more attractive to the well-rounded UVA student and better suited to produce our vision for the “UVA Engineer”, including increased interaction with the Business and Law Schools, undergraduate teaching opportunities, and improved access to overseas study programs.

C.2.4 Student Satisfaction

While a core group of students are pleased with the Electrical Engineering program, overall student satisfaction is below where we would like it to be. As an example, analysis of the results of our 2002 EBI student survey indicated that UVA Electrical Engineering students were much less likely than students at other schools to recommend their program to close friends and did not feel that the program experience fulfilled their expectations. As stated above, this low satisfaction undoubtedly is a cause of the poor perception that many first year students have of Electrical Engineering. They hear from other students (many of whom are likely Electrical Engineers themselves, judging from the student satisfaction data) about the “dissatisfaction” with the program and stay away.

While we as a faculty often dismiss negative student sentiment as “they don’t know what’s good for them” or “they’ll thank us later,” we must tune into concerns and complaints from our own students. Pedagogical research and common sense dictate that students are much more likely to learn well if they are excited about and enjoy their program [Frye97]. In addition, while we may claim that “they’ll thank us later,” our surveys of graduates five years out show us that they do not, with results somewhat improved from the time of graduation but still well below the level where we would like them to be. Therefore, a necessary step to improving our program is to understand what are the main points of student dissatisfaction. The proposed work includes surveys and focus groups to identify these points, which we will then work to address.

C.2.5 Alumni Relations

Maintaining close ties to alumni is essential for student internship and job placement, quality outside advisory committees, and development. We have had some recent success with alumni relations, including an effective Industrial Advisory Board and the establishment of our
department’s first two endowments. In addition, the Department received around $10,000 per year in annual alumni gifts that can be used for the general support of the Department.

Short-term student satisfaction can be tied directly to long-term alumni relations. Our plans to address student satisfaction will therefore no doubt help improve such relations. We must also improve our communication links to our alumni via newsletters and special events. In addition, we must establish and publicize initiatives that would be attractive to potential employers and donors, such as working on a large project with significant engineering and societal value. We will explore all of these opportunities as part of the proposed work.

C.2.6 Prior and Ongoing Efforts

While many of the above issues have only recently become acute, they are not entirely new. The ECE faculty has long been working to improve the Electrical Engineering undergraduate program, and many efforts have met with great success. We detail a few of these prior and ongoing efforts here.

Like most fields, the body of knowledge in Electrical Engineering is and always has been growing rapidly. A natural result of this is an ever-increasing number of courses and course requirements. In 1999, the ECE faculty realized that the course requirements had grown to the point where Electrical Engineering students had very little flexibility in their course selection, both within the Electrical Engineering program and in terms of opportunities to take non-technical courses. Recognizing our students’ wide range of interests (see Section C.2.3) and the educational benefit of allowing students to select focus areas within Electrical Engineering, we reduced the number of required courses and increased the number of Electrical Engineering and unrestricted electives. This shift has been met with universal approval.

We strongly believe and our experience has shown that involving undergraduate students in research projects can add great value to the educational experience. We therefore make great efforts to provide our students with undergraduate research opportunities. In fact, all of our fourth year students are required to perform a yearlong project, culminating in a written thesis and oral presentation. Each student works closely with a technical advisor in their area of interest and an advisor from SEAS’s Department of Science, Technology, and Society (STS). Most students put their full effort into the projects, enjoying the non-classroom-based learning process. The end results are impressive, with students producing theses such as “Classification of Lung Ventilation in Hyperpolarized Helium-3 Magnetic Resonance Images,” “Reactive Ion Etching in an Integrated Circuit Fabrication Laboratory,” and “Design and Implementation of the Dielectric Traveling Wave Tube: A Novel Microwave Device.” Many of these projects are funded by Research Experience for Undergraduate (REU) grants from NSF and are therefore tied directly to active research projects in the department. Some of these REU grants, such as one for the NSF-funded MRSEC Center for Nanoscopic Materials Design, specifically target women and underrepresented minorities for inclusion in research projects. ECE also works with the SEAS Office of Minority Program to encourage women and minorities to get involved with research through the Summer Undergraduate Research Program (SURP).

In 2003, we established a major design experience requirement for the Electrical Engineering curriculum, which we feel adds significantly to the educational experience. All students must...
participate in a multi-disciplinary team of 3-4 students on a semester-long design and implementation project addressing a real-world engineering problem. A particular emphasis is placed on defining specifications, requirements, and design trade-offs. Groups must demonstrate their final systems and prepare written and oral proposals, progress reports, and final reports. Lockheed-Martin has donated $10,000 in support of this effort, including the development of a prototyping laboratory, and the budget for the work proposed here includes funds to enhance the student design experience.

In response to the dropping undergraduate Electrical Engineering enrollment, we have organized several student recruiting efforts over the past few years, including open houses (complete with raffle and interesting demonstrations), advanced undergraduate student panels, and general departmental promotion activities. When we initiated this effort in 2001, there was an immediate and dramatic increase in Electrical Engineering declarations by first year students. However, enrollment numbers have again dwindled, and planning to remedy this problem is a major focus of the proposed work.

The quality basis of any undergraduate program depends firstly on the instructors, and the ECE faculty is blessed with a number of outstanding teachers. Four of the faculty have received University-wide teaching awards and two have received awards from the State of Virginia. On average, course evaluations for the faculty within ECE are very good and generally above the School average. The faculty not only recognizes the importance of undergraduate teaching, but the administration rewards quality teaching in the promotion, tenure, and salary processes, which does not happen at all research universities.

C.2.7 Results from Prior NSF Support

The majority of faculty members in ECE have or have had support from NSF. In this section, we focus on the educational components of some of the grants on which the investigators to be supported by the proposed work have participated.

**Interactive Tools on Microelectronics for Early Science and Engineering Students**

(J. Bean (PI) and J. Groves, $499,800, 9/1/99-8/1/03, NSF grant #9950207)

For the past four years, Dr. John Bean has been developing a Virtual Lab website for microelectronics education. The original website was developed in response to younger students' difficulties with several areas of high school physics and chemistry. Certain concepts, such as Newton's Laws of Motion, are easy to demonstrate and apply. Others, such as electricity and magnetism or quantum mechanics, are likely to remain opaque and apparently irrelevant. This is attributable to two factors: the concepts are based on invisible fields and forces acting at a distance, and there is a scarcity of hands-on experiments and experiences embodying these concepts. To address this problem, the Virtual Lab was built upon cutting-edge computer animation tools and web-based delivery. In virtual reality, it was easy to make invisible fields and forces visible. It was also possible to dissect objects that were not available in the classroom (such as high-tech instrumentation) and objects so small (such as a modern transistor) that physical dissection would require millions of dollars of analytical instrumentation.
The existing Virtual Lab website (http://www.virlab.virginia.edu/) thus starts with the electromagnetic force law and its application to common high school physics experiments such as magnetic induction, electrostatic attraction and repulsion, and simple electrical circuits. It is then shown how these concepts (using the same representations of E&M fields and forces) are embodied in diverse everyday electric devices. However, it is then taken to a higher level as it shows that the same concepts provide the fundamental explanation of how a high-tech object such as a transistor works, or how a state-of-the-art scanning electron microscope or atomic force microscope acquires the images now commonly included in high school textbooks. Each of these topics is illustrated in a common, highly interactive, web page format (based on Macromedia's Shockwave engine) that allows the user to easily navigate through a presentation including up to twenty animations. Each animation is accompanied by a simple, plain English description (for which audio narrations are now being added).

The tools have been successfully incorporated into Dr. Bean’s ENGR 162: Introduction to Engineering course for first year undergraduate engineering students. Over the past three years, the tools have also been used to teach basic microelectronic principles to advanced students at Albemarle High School. Initial tool evaluations have been positive, and additional trials and dissemination are planned. The work has been further disseminated in conference and journal papers [Bean01, Vij02].

**NIRT - Merged CMOS/Molecular Integrated Circuit (Mol-MOS) Fabrication, Analysis and Design**

(L. Harriott (PI), J. Aylor, J. Bean, M. Stan, M. Neurock, and L. Pu, $1,050,000, 8/1/02-8/1/06, NSF grant #0210585, REU: $12,000, 8/1/02-8/1/06)

A major part of our effort in the NIRT project is dedicated to education and outreach. The subject of nano-electronics is highly interdisciplinary and does not fall within the normal pedagogical bounds of engineering and scientific disciplines. We have developed modules for a compelling 3D animation-based website (building on our existing expertise described above) and a graduate level web-published Nanoelectronics course emphasizing the fundamentals of nano-device operation and their giga-scale integration. We are not promoting the singular advancement of one particular class of nano-objects. Instead, our interest is with the question of how these fascinating but disjoint pieces might be fitted together and added to current technology to provide functionality. This is exactly the type of “bottom-line” information we believe members of the general public will increasingly demand. We have supported the development of the web modules through an associated REU program where undergraduate students develop the content of the pages with guidance from faculty and graduate students.

**Small-Scale Dynamic Reconfigurability for Large-Scale Benefits**

(J. Lach (PI), K. Skadron, and M. Stan, $419,784, 9/1/01-8/31/04, NSF grant #0105626, REU: $12,000, 9/1/03-8/31/04)

The primary focus of this project is the exploration of the use of small-scale reconfigurability for efficient dynamic adaptation in general-purpose processors. The project works under the basic assumption that different software applications have different execution characteristics, and small-scale reconfigurability can enable the hardware (e.g. branch prediction units, caches, datapath, and other processor components) to dynamically adapt itself to find the best hardware...
configuration for a specific application based on the observed runtime execution characteristics. The project has produced ideas and techniques disseminated in tool development and multiple high-profile publications (e.g. [Lach03, Lu02a, Lu02b, Lu03a, Lu03b, Vij03a, Vij03b, Vij03c, Vij03d, Vij04, Zha02]), including the Best Student Paper Award at the Workshop on Self-Healing, Adaptive and Self-Managed Systems. Both graduate and undergraduate students have been extensively involved in the project, resulting in five M.S. theses (four of which are now pursuing Ph.D.s and will continue working on this and related projects) and seven undergraduate theses. Three of the students supported by this project were women.

C.3 Concepts

As stated in Section C.1, our objectives are to improve the undergraduate Electrical Engineering program both in terms of the quality of education it provides and its appeal to top and underrepresented students. The desired outcomes are increased student enrollment, retention, and satisfaction and improved preparation for Electrical Engineering practice. We have identified three concepts to help us achieve these objectives: a “big picture” approach to the curriculum, restructuring introductory Electrical Engineering courses, and student enrichment opportunities that help prepare our students for engineering practice and leadership roles. We detail these three concepts in this section, and we will develop and assess them over the proposed work period.

C.3.1 The “Big Picture”

As identified in Section C.2, the Electrical Engineering program faces significant problems with respect to perception and student satisfaction. From talking to both students who selected Electrical Engineering as a major and those who did not, we have discerned that many students simply do not know what Electrical Engineering is as a discipline, and therefore do not see its importance, applicability, and exciting challenges. We expected this from many first year students not familiar with any engineering discipline, but we were surprised to find that many of our own students (even those three years into the curriculum) did not fully understand Electrical Engineering as a discipline, much less the role of individual courses and material topics. Therefore, first year students are easily swayed away from Electrical Engineering by rumors of student dissatisfaction and curriculum rigor, as they do not see the entire program’s relevance and applicability to real-world engineering practice. Even many students who chose to major in Electrical Engineering with some vision of the field as a whole do not understand the context and importance of individual courses and material topics throughout the curriculum. This is particularly troubling when one considers pedagogical research that dictates the importance of context and motivation in student learning [Boo01, Fink01, Lao01], especially early in the curriculum [Frye97]. Indeed, we identify this issue as a primary source of student dissatisfaction and an impediment to quality education.

Much of this problem is due to our curriculum being quite fragmented. While course prerequisites have been established that dictate the proper material sequence, there is no compelling theme that ties the curriculum together. Students get wrapped up with individual courses, and they do not see the big picture of Electrical Engineering as a discipline and miss the grander motivation for course topics.
We propose to develop a “big picture” design project for the program that provides prospective majors a better understanding of Electrical Engineering as a discipline and provides current majors context and motivation for individual courses and material topics. This picture will take the form of a large system with engineering and societal importance. Each course in the curriculum will be identified with system components and enabling technologies, which will then be designed and built in the associated course laboratories and projects. Through this system, prospective majors will be able to better understand what Electrical Engineering is, and current students will be able to place courses and material topics in context. By providing both curriculum-level and course-level answers to the all-too-common student question “why do I have to learn this?”, student learning, satisfaction, and appeal will improve. The proposed work will establish and provide a preliminary analysis of a “big picture” design project for the program.

In addition, a “big picture” project will make Electrical Engineering more accessible to K-12 students. Concepts can be presented via tangible systems and relatable applications. Current students can even take their projects to primary and secondary schools throughout the Commonwealth of Virginia to promote Electrical Engineering to the potential engineers of the future. A particular effort will be place on reaching students in rural and inner-city schools, who typically are not exposed to fields such as engineering and who are less likely than their suburban peers to go on to college.

This project will also be used to promote four-year degrees in Electrical Engineering to students currently enrolled in community colleges. Many such students have chosen community colleges because they do not see the practical benefit of a four-year degree. The “big picture” project will help present our curriculum to the students in an application-oriented and practical way.

C.3.2 Restructuring Introductory Courses

Given that the “big picture” project is to begin early in the curriculum, restructuring the program’s introductory courses may be necessary so that the project can be properly incorporated. However, the primary motivation for this concept exists independently of the “big picture” concept. Like most engineering disciplines, Electrical Engineering has traditionally relied on a curriculum structure that introduces students to theoretical groundwork in early courses, and applications and contexts of that theory are explored only in more advanced courses. While mathematics and basic sciences are naturally taught independent of any engineering application context, introductory courses within engineering disciplines often forsake application and context for theory. For example, one of our introductory course sequences teaches second- and third-order circuit analysis before electronics applications using first-order analysis are explored. Essentially, we are telling our students, “Trust us – you will eventually see the practical use of this theory,” while exposing our students to electronics applications of first-order circuit analysis would not only enhance their understanding of that theory but also motivate and put into context the subsequent second- and third-order analysis theory.

The three sets of introductory courses we will investigate for restructuring are the sequence of ECE 203 (Introductory Circuit Analysis) and ECE 204 (Electronics I), ECE 200 (Science of Information), and ECE 230 (Digital Logic Design). For all three sets, the goal is to provide
students better context and practical application of the theoretical groundwork, thus improving their ability and increasing their motivation to learn the material.

The above circuit analysis example is taken from the ECE 203/204 sequence, which students typically take in their second year at the university (first year in the Electrical Engineering program). Currently, ECE 203 is focused almost exclusively on analysis and ECE 204 on electronics. We will explore approaches to restructuring these courses to interweave analysis and electronics.

ECE 230 has always been a class students have found interesting. They seem better able to absorb the discrete nature of digital circuits, and the concepts become tangible in the laboratory exercises. However, like the ECE 203/204 sequence, the course begins with an in-depth exploration of theory (i.e. Boolean Algebra, logic minimization, etc.), and it is almost halfway through the semester before the students are exposed to circuits implementing a relatable application (e.g. adders, multipliers, counters, etc.). We will explore a course structure that presents the applications first and works backwards to the underlying theory. For example, we can first introduce the functionality of a simple adder, treating it as a black-box within a system, such as the “big picture” project. Then we can go inside the box to reveal the underlying gates and the Boolean Algebra theory that was used to design a “good” adder. Finally, the students can then use their understanding of adder functionality and Boolean Algebra theory to explore various adder implementations that trade off circuit metrics such as area and delay. This approach will also enable the laboratory exercises to be more application-oriented earlier in the semester.

ECE 200 is a course taken almost exclusively by first year students, as it counts as a “Science Elective”, which is required of all first year engineering students (other choices include Chemistry II, Physics II, Biology I, and Introduction to the Science and Engineering or Materials). This course, first offered in 2001, has provided the Department a unique opportunity to present a comprehensive overview of Electrical Engineering (both the program and the discipline) to undeclared students. However, the course has not yet been assessed in terms of measurable outcomes. We will therefore incorporate this course in our detailed assessment plan (see Section C.5) to see if/how it has helped increase student enrollment, retention, and satisfaction. Based on these results, a restructuring of this course may be in order.

In addition to these independent course efforts, all of the introductory courses must also be restructured with a comprehensive vision (e.g. to best incorporate the “big picture” design project). This way, young students will not only learn how the material relates to the entire curriculum and engineering practice, but they will also see how the courses they are currently taking relate to each other. This is especially important for these introductory courses, as almost all of the same-year students take these courses at the same time.

C.3.3 Student Enrichment Opportunities

As discussed in Section C.2.3, the engineering students at UVA have a diverse set of interests, and we encourage the students to explore them, hoping to produce leaders not only in technical innovation but in industrial management, engineering education, business development, technology law and policy, etc. While we have already done much to facilitate students pursuing
diverse interests, there is much more that can be done to attract future leaders to Electrical Engineering and enhance their educational experiences outside of the classroom.

Several advanced undergraduate students have expressed an interest in being more involved in the educational process. Currently, the role undergraduates play in the curriculum is primarily as graders, which provides little benefit to the students. We intend to create more roles for advanced undergraduate students to play in the educational process, such as being advisors to younger students in their “big picture” design projects and teaching assistants in the hands-on labs. This will be a good experience for the undergraduate teachers, and it will also increase the positive interaction between advanced undergraduate students and first and second year students. Other educational opportunities will include advanced students visiting primary and secondary schools to expose young students to Electrical Engineering, using the “big picture” design project as a tangible tool to help the students relate to the field.

One of the benefits of the hands-on nature of the “big picture” project and the revised introductory courses is that students will be better prepared for engineering practice earlier in the curriculum. This benefit increases the opportunities for internship and co-op experiences after their second and third years in the program, as they will be better prepared to make contributions to the companies’ projects. We plan to formalize the process for applying for internships and co-ops and actively identify and persuade companies to participate, enabling a larger number of students to receive this beneficial experience. Similarly, we intend to increase the department’s undergraduate research experience opportunities through coordinated REU applications and development efforts.

Many students would like to spend a semester studying in a foreign country, and there is significant educational value in such an experience. In addition, we would like our students to become leaders not only within the country but throughout the world. In order for our country to maintain its position as the world’s technology leader, we need engineers who are able to work in foreign countries and with people of diverse cultures. However, the current structure of our curriculum makes it difficult for students to spend a semester abroad without falling an entire year behind students in their academic class, something most students are hesitant to do. Given the relatively small number of faculty in our department, most courses are taught only once per year, and prerequisites dictate that course sequences be followed. As a result, students interested in studying overseas typically either reluctantly forego the experience or select a major that enables them to do it without falling behind in the curriculum. We will work to eliminate this problem by identifying universities and programs throughout the world that offer courses that can substitute for the courses the students would take if they did not travel abroad. That way, students can return the following semester and remain in sequence. In addition, we will explore opportunities for overseas internships and co-ops, enabling students to follow a semester overseas with a practical work experience while immersed in another culture.

The large number of students who are interested in business and law calls for the establishment of formal interdisciplinary programs, projects, and research opportunities with the renowned Business and Law Schools at UVA. Last year, an Engineering Business minor was approved by SEAS. ECE must build upon this program and identify other opportunities for our students. This will attract students to the Electrical Engineering program, enrich their educational experiences, and prepare them to become leaders in their field.
C.4 Statement of Work

In the proposed work period, we will plan and assess the impact of the three concepts laid out in the previous section. In the end, we will have a detailed plan for implementing a comprehensive department-level reform, including initial results from the assessment plan detailed in Section C.5. In addition to applying for a subsequent DLR implementation grant, this plan will be submitted to School- and UVA-level administrators to lobby for financial support and project laboratory space. We will also submit the plan to possible industrial and alumni donors, something that will be made easier with a set of technically and socially significant “big picture” projects to help motivate and make tangible the effort. The overall project will be lead by PI Lloyd Harriott, Virginia Microelectronics Consortium Professor and Chair of ECE. This department-level reform will require the cooperation of all ECE faculty, not just the co-PIs. Therefore, Dr. Harriott will also lead the effort to obtain faculty buy-in, providing incentives, training, and support to faculty as appropriate.

The “Big Picture”

• We will identify and assess a set of possible curriculum-spanning systems and projects with both engineering and societal importance. Examples include systems such as wireless communication and data networks, wireless sensor networks, and various wavelength antenna arrays; and projects such as a space exploration probe, a radio telescope, and a smart home.

• We will plan the integration of a system or project into our existing curriculum. An important aspect of this planning is managing the potentially prohibitive logistics of a fully integrated curriculum-spanning project. Initial investigation suggests that the project be modular for decomposition into individual courses with the interfaces between each module clearly defined. Each project component can then be integrated into the “big picture” system. Therefore, when students are learning about a particular topic or performing a laboratory exercise, they explicitly see how it fits within the entire curriculum and discipline. Given that most large systems are decomposed into modules, this approach should make the project logistically feasible, while maintaining the highly desirable “big picture”.

• We will plan a seminar for first year undergraduates where we present the “big picture”. This will act as an active student recruiting mechanism.

• We will prepare a plan to disseminate the “big picture” concept to other universities, enabling Electrical Engineering programs across the country to incorporate such activities into their own curricula.

• We will also prepare a plan to expose the “big picture” project to primary and secondary school students throughout the Commonwealth of Virginia, giving them a tangible way to relate to Electrical Engineering as a discipline. A particular effort will be place on reaching students in rural and inner-city schools, who typically are not exposed to fields such as engineering and who are less likely than their suburban peers to go on to college.

• Opportunities for using the project to expose community college students to our four-year engineering program will also be explored.

• This effort will be lead by John Bean, John Marshall Money Professor of Electrical and Computer Engineering. Dr. Bean’s experience teaching ENGR 162 and working on his NSF CCLI grant give him the perspective to plan and carry out this concept.
Restructuring Introductory Courses

- We will examine the current structure of the ECE 203/204 sequence and identify approaches to interweaving circuit analysis and electronics in a way that enables students to see practical applications of analysis as they are learning it.
- Similarly, we will restructure ECE 230 so that students are exposed to relatable components and systems at the beginning of the semester to provide better motivation for the underlying Boolean Algebra and logic minimization.
- We will explore the role of ECE 200 as a recruiting and discipline information dissemination mechanism, including how the course can reach out to students who otherwise would not consider Electrical Engineering.
- All of these courses will also be examined together to determine the best method for incorporating the “big picture” project into the early curriculum and for enabling the students to see how the courses relate to each other within the discipline.
- This effort will be lead by Michael Reed. Dr. Reed has helped develop many of the introductory courses in the curriculum, including ECE 200, 203, and 230.

Student Enrichment Opportunities

- We will investigate and develop the various student enrichment opportunities detailed in Section C.3.3.
- For increasing internship and co-op opportunities, we will work more closely with ECE’s Industrial Advisory Board, leverage our current and create new industrial relationships, and explore the possibility of subsidizing internship salaries for the first few years, while the companies are buying into the program. This will also help our research programs, as we will establish better relationships with industry.
- Using the money in the budget for undergraduate students, we will hold a competition among our advanced undergraduates for two paid Undergraduate Teaching Fellowship positions. These Teaching Fellows will act as advisors to younger students in their “big picture” design projects and teaching assistants in the hands-on labs.
- We will work with primary and secondary schools around Virginia to create opportunities for advanced undergraduate students to visit the schools and expose young students to Electrical Engineering, using the “big picture” design project as a tangible tool to help the students relate to the field.
- Using the new Engineering Business minor as a starting point, we will work with the Business and Law Schools to identify and develop additional collaborative and student enrichment opportunities. Examples include engineering entrepreneurship and patent law courses, research projects, internships, and other activities.
- We will work with the International Programs office on identifying overseas universities with engineering curricula that offer courses that could be suitable replacements for the ones we offer. Dean James Aylor has identified international educational opportunities as a SEAS priority, and we therefore expect significant School-level support for this endeavor. We will also explore international opportunities for internships and co-ops.
- All of these activities will be disseminated to other Electrical Engineering programs via publications and education seminars, as students across the country would benefit from the enrichment opportunities described here.
- This effort will be lead by John Lach, Assistant Professor of Electrical and Computer Engineering. In 2002, Dr. Lach lead the effort to establish a Computer Engineering graduate
program that now is in its second year of operation. He also planned and implemented a new capstone design project for Computer Engineering students, and since 2003 he has been the chair of the SEAS Undergraduate Research and Design Symposium.

C.5 Assessment Plan

The objectives of the above efforts are to improve the quality and student-appeal of the Electrical Engineering program. To assess the results of these efforts, we have identified the following measurable outcomes: enrollment (total and number from underrepresented groups), retention, satisfaction (student, graduate institution, and employer), and preparation for engineering practice. While data for enrollment and retention is readily available, satisfaction and preparation are more difficult to gauge and quantify. While student satisfaction certainly affects enrollment and retention, more direct measures are necessary. We will therefore rely heavily on surveys (augmenting existing School-, program-, and course-level survey mechanisms) to measure these important outcomes.

We currently survey graduating students, alumni, and employers annually, seeking to assess tangible measures of success as well as opinion. In addition, surveys of employers (particularly recruiters) assess how well our objectives match their needs. Like at most universities, individual courses are assessed via end-of-course student evaluations, which we complement with instructor evaluations on the extent to which the stated course objectives were achieved. The proposed project will include the exploration of how to best leverage these mechanisms to measure our satisfaction outcome. In addition, preliminary assessment data will be used to drive planning and implementation over the coming years.

The School’s exit surveys are from students as they complete their program of study. The School analyzes the results and reports the questions with the most positive responses and the most negative responses, School-wide and by major. Also reported are responses that frequent the “best” and “worst” lists over several years. These results are then used to address shortcomings. For example, the School-wide responses had shown consistent dissatisfaction with Physics and Chemistry courses. As a result the Dean’s office has been working with instructors in both departments to address these issues. Significant changes in content and presentation have been made in both courses as a result. The students who have been affected by these changes will begin to graduate in the next academic year, and we will be monitoring the surveys to see if the results of the improvements are discernable. It is these surveys that provide most of the dissatisfaction data discussed above, leading to the motivation for the proposed effort. It will therefore be a useful assessment mechanism for evaluating the impact of this effort’s implementation.

The Office of Institutional Assessment recently conducted a survey of UVA graduates from classes of 2001, 1998, 1993 and 1983 (3, 5, 10, and 20 years out). This longitudinal study was commissioned by UVA’s Board of Visitors and had as its primary focus the study of attitudes and activities related to diversity. The School’s representatives were permitted to include up to ten questions that would be asked of its graduates. Our program’s approach to measuring the achievement of program objectives via the survey was to ask for evidence rather than opinion. For example, one phrase in our departmental objectives states that graduates will “make tangible contributions”. Evidence to assess this objective was solicited with questions asking whether the
graduate published a technical article or book, was granted a patent, presented their work in a public forum, etc. Evidence of lifelong learning was gathered with questions asking whether the graduate took courses, participated in company training, obtained a certificate or advanced degree, etc. Survey results were made available only recently and are currently being analyzed. In future installments of this survey, after students affected by the proposed reformation have graduated and are a few years out, we will be able to measure our stated outcomes over the long-term. Ultimately, we see these surveys as being the most useful for assessing the quality of preparation for engineering practice we provide our students and for determining how many of our graduates have become leaders in their field. The alumni survey is therefore essential for the effective assessment of the proposed reforms.

In an effort to assess how our program objectives align with employer needs, we distributed a survey to recruiters who visited the engineering school for career days last fall. The survey contained open-ended questions asking what skills and attributes were sought in engineering graduates. Given that one of our underlying objectives is to make our program more relevant to engineering practice, these surveys are key. We will continue to refine these surveys (including questions regarding the specific concepts outlined in this proposal) and work to increase company participation in the coming years. In addition, we will seek feedback from the companies on how well our graduates are prepared for engineering practice and whether or not they are becoming leaders in their companies.

The most timely feedback we will receive will come from individual coarse surveys. We will therefore plan supplements to the existing generic surveys defined by the School in order to seek feedback on the specific objectives and outcomes we are addressing in this proposal.

By the end of the proposed planning period, we will have preliminary assessment data (primarily through individual course surveys) to guide the subsequent implementation process. In addition, we will have planned the full assessment process to be instituted during implementation.

This effort will be lead by Joanne Bechta Dugan, Professor of Electrical and Computer Engineering. Dr. Dugan had lead previous department-level assessment activities, including our most recent self-study for ABET accreditation.

C.6 Broader Impacts

(I am still working on this section – jlach)
D References


