Integration of Electrical Engineering Core Labs with Major Design Experiences

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Motivation: Michigan Tech has taken bold steps to structure a design experience that begins the moment a student sets foot in the department. Michigan Technological University underwent a remarkable transformation as the conversion from quarters to semesters unfolded over the 2000-2001 academic year. The Electrical and Computer Engineering department took advantage of the opportunity to enhance the department's laboratory experiences as well. The ECE department had followed a traditional curriculum model that had a lab directly associated with each core course. The decision was made to create a set of core laboratories that were separate but aligned in a co-requisite structure with the core academic courses, Table 1.

Table 1. Core Labs - AY 2000-2001

Semester	Lab	Co-requisite Core Courses
Fall 2nd Year	ECE Lab 1	Intro to Signal Processing Digital systems
Spring 2nd Year	ECE Lab 2	Circuits Linear Systems
Fall 3rd Year	ECE Lab 3	Electronics Microprocessors
Spring 3rd Year	ECE Lab 4	Electromechanical Energy Conversion Communications

Each lab was created by faculty members with significant experience and expertise in the individual subject areas. And yet, there was considerable turmoil in the administration of the labs. Disconnecting the labs from the lecture courses also severed individual faculty members' responsibility for the lab. Everyone became responsible, and so, no one was responsible. The co-requisite relationship between the core courses and their associated lab required a level of synchronization that was no longer possible. Key concepts from lectures were necessary for successful accomplishment of the laboratory tasks. Delays in the lecture course needed to be matched by delays in the labs. When this was not possible, due to other schedule constraints, needless frustration was visited upon the students, instructors, and eventually the ECE Department Chair. Having elevated themselves to the attention of the chairman these problems were cause for great concern. The chairman, acting forthrightly, found a champion and laid out the challenge: create an

ECE laboratory experience that will be recognized as one of the best in the nation by 2006.

Survey assessments from all of the lab courses indicated an overall satisfaction with the lab experiences but a high level of frustration caused by misalignment between the theory class and the labs. One student identified a three to four week difference between tasks in the lab and theory presented in the co-requisite lecture despite deliberate efforts to adjust the lab schedule. A further consequence of the co-requisite structure surfaced when marginally successful lab students were forced to drop a lab because of difficulties in the co-requisite courses. It was clear that at least part of the solution must be to realign the lab experiences with respect to the lectures and eliminate the co-requisite strategy. The design challenge was to create a set of lab courses that will approximate the existing lab curriculum within the existing two academic year window, decouple the co-requisite problem, and stop global warming. The proposed structure is reflected in Table 2.

Table 2. Core Labs - AY 2003-2004

Semester	Lab	Prerequisite Core Courses
Fall 2nd Year	ECE Lab 1	None
Spring 2nd Year	ECE Lab 2	Intro to Signal Processing Digital systems
Fall 3rd Year	ECE Lab 3	Circuits Linear Systems
Spring 3rd Year	ECE Lab 4	Electronics Microprocessors

Lab 1 forms an introductory process that transitions the first year student from the common first year engineering curriculum into the ECE department and begins the process of preparing the student for his or her major design experience. This lab serves several purposes. First, it introduces the basic hardware and software tools of the electrical engineer. Basic measurement equipment is introduced along with a set of experiential activities designed to lead to student to discover for herself, the basic electric circuit laws. Safety and proper circuit construction techniques are emphasized to facilitate more complex design and construction activities later in the curriculum. The introduction of modeling and simulation tools prepares the student by walking them through the theory, model, simulation, measurement and conclusion cycle with the tools of practicing engineers.

In addition to these cognitive and psychomotor activities, assignments stressing affective domain learning are also included in order to strengthen individual motivation and establish a stronger connection to both industry and the market place. Students are required to produce a book review of "The Chip" by T. R. Reid. The Chip is a historical biography of the inventors of the monolithic integrated circuit. The book details Jack Kilby and Robert Noyce's intellectual response to the grand challenge of their day. The pervasiveness of the microchip makes it easy to provide relevant context for every student in the class. The book review focuses the student on his or her personal emotional and intellectual reaction to book. This exercise is complemented by guest presentation from faculty who talk about their research and the "grand challenges" in today's engineering arena. The ultimate goal of the lab sequence is to provide the students with the intellectual and physical skills to move forward at the same time we energize the interest and passion that first brought them to the field of electrical and computer engineering in the first place.

The fact that Lab 1 has no prerequisites enables the other labs to slip with respect to their co-requisite classes. In addition to satisfying one of the basic problem criteria and solving a frustrating situation for all concerned, this slippage has several beneficial side effects. First, because the lab experiences trail the theoretical material by a semester, student learning continues to be reinforced through recall and exercise. Granted there is some loss over the semester/summer break, but this is quickly overcome as more recent experiences refresh memories. For those students who achieved only a partial mastery of the material, the experiential activities offer abundant re-teaching opportunities using an approach that may be better suited to the individual's preferred learning style. Finally, more challenging material can be presented. Under the previous paradigm, lab experiences waited on theory or lead theory. Thus the more interesting activities ended up at the end of the schedule when the student's abilities had risen to an appropriate level. The new paradigm offers the opportunity to begin the semester with experiences that previously had been reserved for the end. For example in the old Lab 2 basic measurements, PSpice, and simple op-amp circuits filled the first half of the semester while the co-requisite courses progressed. It was not until late in the semester that the students were challenged with active filter design. Now this activity starts off the new Lab 3. By the end of this Lab the students are designing, building, and testing an AM transmitter and receiver.

Labs 2, 3 and 4 follow a similar pattern. Lab experiments have been organized in a continuum with highly structured "cook-book" style experiments at one end and performance-specification driven subsystem design at the other. Each course begins with a traditional "cookbook" style experiment that reintroduces the student to the lab environment, gives them the opportunity to refresh old skills while preparing for the immediate adventure. Subsequent experiments are structured to place the learning objective just out of the student's intellectual grasp by presenting a design challenge and constraint system that requires the use of previous learning in new ways. For example, in the beginning of Lab 2 the students take 4 weeks to learn to use a VHDL development system and design and build an 8-bit adder. By the end of the semester they are designing and building a multiplexed fiber optic transmitter and receiver.

In Lab 3 each design challenge is selected to fill a requirement in a system block diagram that supports a larger design, that of an AM transmitter and receiver. The students are broken into groups to design each functional block; transistor amplifiers, active filters, linear power supplies and oscillators; while the instructor provides contextual clues that enable them to connect-the-dots as the cumulative functions produce a larger design. This pattern, combining structured "cookbook" lab experiences with cumulative design activities is repeated through the overall lab curriculum and confronts each student, singly and in groups with increasingly challenging design problems.

These technical exercises are combined with the “softer” communication skills. The ability to communicate both in writing and orally is integrated into each level of performance. Each lab course carries a requirement to produce written documentation as well as the traditional lab report. Furthermore, every student is provided the opportunity to explore and present a current topic in engineering. In Lab 1 and 2 students are required to present 5-10 minute discussion on a current topic in Electrical or Computer engineering. Research for these presentations is confined to technical publications and journals to avoid a “Popular Science” approach to dilute the academic inquiry. The intent of these presentations is two fold. First and foremost, the students have an opportunity to follow up on any spark of interest that may have been generated by their reaction to “The Chip” in Lab 1. Also of great concern is the regular opportunity to practice getting in front of a group of people and speaking; a skill both highly prized by industry and dreaded by most humans. In lab 3 students are allowed to select a research topic from a list of electrical and computer engineering buzz-words. In Lab 4, student teams are given unique design challenges. As part of the design deliverables each team presents its design and the challenges associated with it to the rest of the teams expanding both their own presentation skills and the other teams’ technical knowledge simultaneously

The changes in the lab sequence were both motivated and constrained by the transition from quarters to semesters. Preserving the integrity of student transition plans required a phased roll out of the new curriculum over two years. Each year’s curriculum was deployed behind an advancing group of students who were completing their degrees. Academic year 2000 – 2001 was the year of the sophomore, AY 2003-2004 is the year of the junior lab. As students with transition plans advance through the system and graduate, the new curriculum is constructed and deployed behind them.

The changes in the lab philosophy required changes in both the curriculum and student culture that not all stakeholders were positive about. The fact that the most challenging exercise of the previous paradigm has become the launch point for the new has generated it own set of frustrations in the student body. The undergraduate students regularly express their concerns about the level of effort required relative to a one credit course. The graduate teaching assistant lab instructors are also challenged when multiple lab assignments require them to hone their skills in digital logic, signal processing and oscillator design simultaneously.

Ultimately, by integrating the department’s core laboratory courses into an overarching “crawl-walk-run” philosophy, EE and CpE students are well prepared to exploit the opportunities presented during their ABET major design experience. The true winners, at the end of the day will be the students who walk out the door with a complete set of technical and professional skills that will enable them to hit the ground running in any engineering environment.

One follow on study that immediately presents itself is an examination of student performance and preparation for the major design experience pre and post transition. We are presented with a unique opportunity to examine the last wave of students from the previous paradigm as they conclude their major design experience at the end of AY 2003/2004. This group's performance and perceived preparation could be measured against the leading edge of students prepared under the new paradigm as they enter their experience in the Fall of 2004. This study may shed some light on the question of whether disconnecting the labs from the theory courses has produced any improvement in either performance or perceived preparation. Assuming a happy outcome with regard to the overall efficacy of the program, it should also provide calibrating inputs to fine tune the program over time.

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