Developing Laboratory Courses in a Resource-Constrained Environment

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ABSTRACT
Laboratory courses are an essential part of most engineering programs. The practical applications of engineering theory motivate student interest and enhance student learning of the subject matter. However, many laboratory courses have special requirements that can exceed the resources of small departments.

At the University of Tulsa, the Electrical Engineering department contains a laboratory that has space and equipment for approximately twenty students. The room is used for microprocessor design and senior capstone design courses in the fall semester, and digital logic and electronics laboratory courses in the spring semester. Because the enrollment in these courses typically exceeds room capacity, we had to deviate from the traditional model for developing these laboratory courses.

A traditional laboratory course is often scheduled for a three-hour time slot during the week, and students work on the assignments during this period. However, due to our resource constraints, we have modified this approach. To ease space constraints in the lab, assignments are "self-paced" with specific deadlines. The lab is open all day during the week, and students may work on the assignments as time and space permits. Teaching assistants are available during scheduled office hours throughout the week for consultation and grading. This paper discusses the application of this approach to the development of specific laboratory courses.

BACKGROUND
An important part of any engineering curriculum is laboratory courses, which supplement the theoretical knowledge gained in lecture courses with practical applications. ABET requirements stress the importance of engineering students obtaining the ability to design and conduct experiments[1]. Ideally, this would be accomplished by supplementing each engineering course with a co-requisite laboratory. However, the requirements of laboratory courses can often exceed the resources of most small departments.

At the University of Tulsa, the Electrical Engineering department contains a laboratory that has space and equipment for approximately twenty students. In order to meet ABET requirements, we typically offer two laboratory courses per semester. During the fall semester, the laboratory is used by both a microprocessor design course and a senior project design course. For the spring semester, the room is occupied by laboratory courses for both digital logic and electronics.

A brief history lesson is in order to understand how these constraints developed. Twenty years ago, separate laboratory space existed for both the digital logic and electronics courses in our department. At that time, digital logic was only required for sophomore-level Electrical Engineers. For the junior-level electronics lab, class size dictated that the lab be taught in two sections. As technology advanced, the digital lab assignments become more complex, which required time outside the normal class period. In addition, our Computer Science department chose to make the digital lab a required part of their program, effectively doubling class size. During the same period, the number of Electrical Engineering students declined slightly, which reduced the size of the electronics lab. Instead of two full sections of this lab, only one and a half were needed. This allowed students to move freely between sections.

Also during this time, space was needed for research and advanced laboratories, which affected the available space for the digital lab. Eventually, we had to combine the digital logic and electronics labs in the same laboratory. The result is a shared space for the equivalent of four lab sections in a room that was originally designed to support only two sections. This paper describes the approach used to develop laboratory courses that accommodate our resource constraints, using the development of the spring semester courses to illustrate this approach.

IMPLEMENTATION

The laboratory courses offered during the spring semester are co-requisites to lecture courses for digital logic design and electronics. A traditional laboratory course is often scheduled for a three-hour time slot during the week, where students work on the assignments during this period. However, due to our resource constraints, we have modified this approach. To ease space constraints in the lab, assignments are "self-paced" with specific deadlines. The lab is open all day during the week, and students may work on the assignments as time and space permits. Teaching assistants are available during scheduled office hours throughout the week for consultation and grading.

Digital Design Laboratory

The Digital Design Laboratory is one of the courses that uses the lab during the spring semester. This course is required for all Electrical Engineering and Computer Science undergraduate students, with typical enrollment of forty to fifty students per semester. Since we only have space and equipment for twenty students, the self-paced approach has been applied to this course.

At the beginning of each weekly lab session, the instructor gives a thirty-minute lecture using one of the larger lecture classrooms. Students are then dismissed to work on the lab experiments. There are ten lab experiments. Each lab is worth ten points, for a total possible lab course score of 100 points. Labs that are completed one week late are worth eight points, while labs that are completed two weeks late are worth five points. The exception to the policy is for the last three project labs: due to their difficulty, these labs are not due until the end of the semester.

All course information is posted on the course web site, including lab experiment instructions. Students must purchase a kit of parts that are stocked and sold by the local student IEEE chapter, and a set of basic tools. All other equipment is available in the lab.

Students must also purchase a composition book (10-1/4" × 7-7/8", 80 sheets, 5 × 5 quad ruled) to be used as their lab journal. All lab work must be recorded in this journal and checked by an authorized grader. Journals must be submitted to the instructor by the end of the last scheduled lab of the semester.

Since the laboratory course is coordinated with the co-requisite lecture course, the first project is not assigned until sufficient background material has been covered in the lecture course. There are three main parts of the course. The first set of projects help students get familiar with hardware design through practical application of digital logic theory. Next, the second set of projects focus on using programmable logic devices to implement digital designs. Finally, the third set of projects has students use the experience gained from the earlier projects to build digital design projects. More specific information on the course design projects can be found in a previous ASEE paper [2].

Electronics Laboratory

The Electronics Laboratory is the second course that uses the lab during the spring semester. This course is required of all Electrical Engineering undergraduates and others involved in the Electronics courses. Typical enrollment is approximately twenty to thirty students and with a twenty-student limit on space and equipment, there are two lab sections offered each week. In contrast to the self-paced approach of the Digital Design laboratory, the students are required to complete a minimum of one laboratory exercise each week. The electronic labs are broken into four blocks, A through D. Each block consists of three to five individual laboratory exercises. Each succeeding block increases the complexity of the exercise and the circuits involved. Within the block, the particular exercises are randomly assigned to the individual students. This prevents every student doing the same exercise. Each block must be completed before going to the next block. After completing the first three blocks, the students are allowed to select exercises to work from the final block.

Pre-laboratory analysis of the circuits using PSPICE[3] and discussion of the circuit's performance and measurements to be completed is required before the start of the lab. During the lab period, each student is required to build the individual circuits in the lab area and perform the measurements required by the lab exercise. Each lab report requires a discussion of the measured results, comparison to the PSPICE analysis, and how the circuit works. The pre-lab and in-lab work are recorded in a bound notebook. The student submits the lab notebooks to an authorized grader. Grades are assigned based on the completeness of the individual lab exercise.

The Electronics lab's objective is to provide the students with the experience in designing, constructing, and testing a wide range of common electronic circuits. The goal is to develop the capability to combine individual circuits into more complex systems. Therefore, the lab exercise covers circuits discussed in both the Electronics 1 and Electronics 2 courses. This allows the instructor the time to develop the necessary background for the more complex circuits in the Electronics 2 course before requiring them in the Electronics Lab.

OBSERVATIONS AND OUTCOMES

In order to accommodate both courses in a limited laboratory space, we had to incorporate flexibility into the design and administration of these labs. Fortunately, these constraints have

not appeared to affect the students' development of laboratory skills. In fact, the flexible approach has enhanced student skills by requiring good time management and independent work. Students have commented that the practical assignments and discipline required to complete these assignments in a timely manner have enhanced their understanding of engineering design. They also liked the exposure to a wide range of design projects.

BIBLIOGRAPHIC INFORMATION

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[3] PSPICE, www.orcad.com.

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