Work in Progress - A Program to Incorporate Portable Labs Into Lecture-Based Electrical and Computer Engineering Courses

Bonnie Ferri, Jill Auerbach
Georgia Institute of Technology, bonnie@ece.gatech.edu, jill.auerbach@ece.gatech.edu

***Abstract* – This Work in Progress paper describes the Teaching Enhancement via Small-Scale Affordable Labs (TESSAL) Center at Georgia Tech. This center is devoted to the development and implementation of distributed labs, that is, experiments that can be done by students at home or in the classroom. The objective is to introduce experiment-based active learning into typical lecture-based courses. To support distributed labs, an infrastructure must be built that includes logistical plans, instructor resources, student resources, and web-based support. A total of 1244 students at Georgia Tech have participated in TESSAL activities, and assessment is underway to determine its effectiveness in enhancing the learning of fundamental concepts and in inspiring the students in the topics being taught.**

Index Terms – active learning, distributed laboratories, portable experiments.

INTRODUCTION

Hands-on experiments can be very valuable to a learning experience, but they are typically relegated to centralized laboratories associated with lab courses. This paper describes a program at Georgia Tech, entitled TESSAL, that develops portable labs and introduces them into a variety of ECE courses that currently do not have lab components. Particular emphasis is placed on introducing laboratory experience into lecture-based courses in an effort to enhance the learning of theoretical material. The program establishes a template for the lab modules, develops logistical support, and determines best practices for establishing this type of program.

There are several modes of implementation that course instructors can use for these labs, specifically, a demonstration done by the instructor with interactivity by the class, in-class lab done by groups of 2-5 students at their desks, or a lab or project done by students at home using their own computers. In order to have a high adoption rate, the TESSAL lab modules have the following features:

- Target a fundamental concept that is theoretically difficult to understand
- Low cost
- Portable that can be done in class or at home
- Associated web component

The TESSAL Center was introduced in a previous paper, [1], and the current work in progress is discussed here. There are currently 12 laboratory modules that have been either fully or partially developed under the TESSAL program. The topics covered are in the areas of signals and systems [2], digital logic [3], control systems, electromagnetics, and power systems.

The modules have had widespread usage at Georgia Tech. Twenty-one professors have been involved in their development, usage, or assessment in 8 Electrical and Computer Engineering courses and 2 Mechanical Engineering courses. A total of 1244 students have participated in this program with an additional 396 middle school and high school students using the modules during summer camps.

A variety of assessment tools are used including pre- and post- student surveys, specific test questions relating to the material, and pre- and post- tests. These assessment tools provide feedback about various aspects of using the modules and contribute to a best practices inventory.

One of the challenges in this program is gaining instructor adoption and cooperation since instructors who teach theoretical lecture-based courses are often not comfortable with experiments. The supporting website [4] is being developed to provide enough support and information for these types of instructors and for teaching assistants.

Website Components

The online resources that are being developed for instructors include instructions for building the lab, list of frequently asked questions that students might have, and a video of implementing the lab. The online resources for students include an on-line summary of the fundamental (theoretical) concepts being explored, the lab or project description, supporting computer code, and a video giving an explanation of how to perform the lab (available on-line or in a version downloadable to an IPOD).

In addition, each experimental module has a set of online test problems that are typical of those that might be found on a test in the lecture based course. These test problems are the important last step to tying the experiments back to the theory in the class and are meant to overcome a common limitation of in-class experimental demonstrations and web-based virtual experiments. That is, students are impressed by the interesting aspects of these demos during the exercise; however, they may not be motivated to review the material when studying for tests, which are based on theoretical problems. The TESSAL sample test problems show students how the experimental concepts can be covered in a standard test. An alternative way to tie the experiments back to the theory in the class is to change test questions to include some practical aspects. This would be accomplished by individual instructors.

Logistical Support

Distributed laboratories do not use centralized laboratories for delivery of the experiments, but they can utilize the infrastructure. In particular, the personnel and equipment that is in place for sophomore and junior-level labs can be leveraged for building these laboratory modules. In-class experiments need the following support: enough modules to accommodate the entire class in 2-5 person groups, a projector to show the instructional videos or informational screen shots, and sufficient TA support to help students and to sign off on the lab. Experience in this program has shown that 2 TAs can be utilized for 20 lab groups. Prior to the lab, the TAs check all the experimental modules for working order.

Fewer TAs and laboratory modules are needed for out-of-class labs and projects (one TA for 25 lab groups). The TA has office hours where students can check out the platforms for ½ day increments: from 9:00am-4:00pm, and from 4:00pm until 9:00am the next morning. Students who plan ahead can reserve the platform over the weekend. Using this mode of implementation, as few as 4 platforms have been sufficient for a class of 50 students divided into 3-person groups [5].

At Georgia Tech, the TESSAL Center has laboratory space that includes 12 computer stations as well as a large number of shelves to store the equipment for the various modules. An alternative would be to house the experiments in one of the centralized laboratories that already exists in an ECE department.

Best Practices

As mentioned above, a major challenge to implementation is persuading instructors to use the experiments. Professors who teach lecture-based courses are often skeptical of the learning curve and the total amount of effort that they would need to invest in the experiment. We have found that if these classes have a TA assigned to them, then the TA is the key to adoption. The TA can try out the experiment, bring the experiment to class, or be in charge of the out-of-class project logistics. The experiments are being designed to minimize the learning curve for instructors and TAs alike.

A working list of best practices for out-of-class experiments includes

- Assignment must be mandatory and thus on the course syllabus to ensure compliance.
- Use a reservation system for students to reserve modules ahead of time.
- Penalize groups 5% for each instance of tardiness (more than ½ hour late).
- Put the modules in small, sturdy boxes; tackle boxes or tool boxes work well to protect the module that might otherwise get damaged if put into a book bag.
- Have a place where students can come to work on the lab during TA office hours so that they can ask questions.

A working list of best practices for in-class experiments include:

- Test all experimental modules before class.
- Ensure adequate time in class for both instruction and implementation phases. The experiment should not be seen as an add-on.
- Strongly encourage all students to come prepared for the lab (or risk not completing it). Preparation includes completing prelab assignments, reading the fundamental concepts tutorial, printing the lab instructions for class, and viewing the instructional video.
- Play the instructional video at the beginning of class after the modules have been distributed.
- Limit the number of TA check points in the labs to a level that can be completed by the available number of TAs during the allotted class period.

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