

Work in Progress - The Costs and Benefits of Using Alternative Approaches in Lecture-Based Courses: Experience in Electrical Engineering

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Abstract - Engineering programs across the country promote the success of their courses to engage students through the use of hands-on projects, cooperative learning and other non-traditional educational strategies. While alternative strategies to lecture-based instruction are preferable in many ways, there are many formidable obstacles to their widespread implementation. The goal of a project funded by an NSF CCLI grant addresses several of these obstacles through the use of portable, low-cost experiment modules in traditional lecture-based courses to enhance the learning environment. This research describes the introduction of these experiments at a top tier university and the lessons learned towards implementing a cohesive program of hands-on experiments into several courses that do not have lab components. In order to understand both the costs and benefits of using portable experiments, the assessment approach used in a systems and controls course is described. Using both survey and test data, the inherent costs and potential benefits of integrating hands-on experiments in lecture-style courses will be examined.

Index Terms – Assessment, engineering instruction, portable engineering experiments, concept inventory.

INTRODUCTION

Engineering instruction is multifaceted in that students need a solid understanding of the theoretical foundation that guides the application of technical expertise and promotes problem-solving skills. This is achieved to varying degrees by curricula that include both classroom and laboratory learning environments. In terms of student response to various instructional strategies, educational research points out that the use of hands-on experiments, cooperative learning and other non-traditional instructional methods are more likely to engage students in the learning process [1]. Many courses in the engineering fields are particularly suited to team-based work for completing open-ended projects and are often the format for senior design courses. Other courses are amendable to the laboratory environment and may require students to complete some designated portion of class-time in the lab. Alternative strategies to “passive” lecture-based instruction are preferable in many ways and characterize a significant portion of engineering education where students cultivate their knowledge through

hands-on experiments [1]. There are many formidable obstacles to the widespread implementation of hands-on experiments. They can be costly in terms of equipment, personnel, training and space. Certain types of engineering courses, such as core and other foundation courses, may include material that is not as conducive to non-lecture based formats, and engineering faculty members are not always open to non-traditional teaching techniques.

The NSF CCLI funded project discussed in this paper addresses several of these obstacles through the implementation of portable, low-cost experiment modules in traditional lecture-based courses. These experiments and the supporting materials are referred to as The Teaching Enhancement via Small-Scale Affordable Labs (TESSAL) Project [2], and include 12 laboratory modules in the areas of signals and systems [3], digital logic [4], control systems, electromagnetics, and power systems.

DESCRIPTION OF PROJECT

The TESSAL Project is basically a “distributed laboratory” that permits the use of portable experiments in a variety of engineering courses. The goal of TESSAL is create a permanent shift away lecture-only instruction in electrical engineering and computer engineering courses. In the current implementation stage, several costs have been identified.

Costs

A primary objective of TESSAL is to keep the costs of materials low in order to acquire enough individual experiments for practical implementation. Other related costs that are more difficult to calculate include those associated with assembling and testing the experiments. Instructor “costs” can be the most difficult to overcome, yet strategies have been developed throughout the TESSAL project that alleviate anticipated resistance and are described in a “best practices” work in progress by Ferri and Auerbach [5]. Regardless of the availability of supplemental material, graduate student support, website resources and pre lab activities, there is a potential loss of lecture time to accommodate the experiment. This lost opportunity must be weighed against the gain in student benefit from using the alternative approach.

Instructor costs are varied and depend upon several factors. There is a “learning curve” for the instructor to learn the basis of the experiment and how to modify the

course to accommodate the experiment. Since this particular cost can be perceived as quite imposing to instructors who are used to teaching lecture-based material rather than experimental material, considerable effort is made to identify before hand the precise material that the modules cover and how to insert them into the course outline. One experience highlights the sensitive nature of instructor time and the misconceptions that can inhibit the willingness to just try using the module. A professor teaching a course in signals and systems was initially excited about incorporating a lab into the class. Once the semester was underway, he starting balking at using the experiment citing pedagogical reasons that did not make sense with respect to the project.

When pressed, he admitted that he had not had time to read the project description. Fortunately, he was amenable to having his TA learn the project and run the experiment, who did such a nice job and the professor was so impressed that he nominated the TA for an Outstanding TA departmental award. Thus, this incident highlights an additional cost of political persuasion by the champion of distributed labs in the department. The process of convincing instructors to invest their time and effort into adopting distributed labs has a learning curve. Identifying early on at least one other instructor committed to expanding hands-on learning can offset this burden.

Finally, evaluation of using the modules is a critical element to shifting the paradigm and achieving more widespread implementation. Without someone in-house whose role is to conduct both formative and summative assessment of the overall project, this can be a costly component and a difficult obstacle to overcome. Yet objective assessment data is needed in order to evaluate the impact of using the modules. Since the TESSAL project identifies three student outcomes, the assessment procedures are aimed at identifying and describing the extent to which those benefits are realized.

Student Benefits

A primary purpose of the project evaluation is to figure out if students benefit from adopting hands-on experiments in lecture-based courses to teach complex engineering concepts. The three expected student outcomes that were identified are specified below:

1. Student achievement on tests/homework/assignments will benefit from the hands-on instructional approach.
 2. Students will be more positive about the course and/or course material as active learners using the modules as well as show more interest in the topic area.
 3. Students will benefit from the hands-on approach in subsequent courses in terms of performance and interests.
- In order to address the three expected outcomes, a variety of assessment procedures are used and are briefly described below in the next section.

Student Achievement

There are two approaches to ascertaining the extent to which student performance is impacted by the hands-on approach. A "Concept Inventory Exam" [6] was developed specifically for the systems and controls course and a quasi-experimental

design used to compare two sections of the course taught by the same instructor. Several questions on the exam pertain directly to the concepts covered by the experiments, which were used in one of the course sections. The control class will complete a post-test at the end of the current semester. For other courses, individual performance on specific test items that correspond to the material that may be covered by the modules is collected and will be compared across control and experimental sections of the same course.

Student Interest

Surveys are used to understand the impact of the experiments on attitudes about course content, relevance of material, application of concepts, interest and motivation about course content, and overall quality of class experience. Preliminary analysis from survey data in a digital logic course show that students report a better understanding of state machines in the experimental classes that used the hands-on experiment to cover the material.

Long-term Student Benefit

Follow-up surveys will be administered to students who took the Systems and Controls course used for the case study. For these purposes, students who were in both the experimental and control group classes will be asked to complete an on-line survey at the end of the subsequent semester. These questions will address issues of knowledge of material, subsequent course-taking behavior and interests in various topics.

Taken together, the project evaluation will provide valuable data about the student experience and the potential for both short-term and long-term benefits of using alternative instructional methods. In addition, the data will assist with improving implementation procedures in order to offset the many costs of revising instruction and the long-held pedagogic beliefs that support the traditional approach.

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REFERENCES

- [1] Feisel, L.D., and A.J. Rosa, 2005 "The Role of the Laboratory in Undergraduate Engineering Education," *Journal of Engineering Education* 94 (1): 121 – 130.
- [2] B. Ferri, J. Auerbach, J. Jackson, J. Michaels, D. Williams, "A Program For Distributed Laboratories In The ECE Curriculum," 2008 ASEE Frontiers in Education Conference, June 22-25, Pittsburgh.
- [3] Ferri, B.H, Ahmed, S. Michaels, J., Dean, E., Garvet, C., Shearman, S., "Signal Processing Experiments With LEGO MINSTORMS NXT Kit for Use in Signals and Systems Courses," *Proceedings of the American Control Conference*, St. Louis, pp. 3787-3792.
- [4] B. Ferri, J. Auerbach, H. Qu, "Distributed Laboratories: A Finite State Machine Module," submitted to the *CS & CompE Education International Conference*.
- [5] B. Ferri, J. Auerbach, "A Program to Incorporate Portable Labs into Lecture-Based Electrical and Computer Engineering Courses," submitted to *2010 FIE Conference*.
- [6] K. Wage, J. Buck, T. Welch, C. Wright, "The Signals and Systems Concept Inventory", *2002 Proceedings of the ASEE Conference*.

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