Learning-Centered Laboratory Instruction for Engineering Technology

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Abstract

One of the most desired educational outcomes of an engineering technology department is the creation of *skillful technologists who are able to approach the design and application of both hardware and software with aptitude and creativity to solve problems*. The technical solutions in today's job market require special skills and training that promote cognitive flexibility, creativity, knowledge transfer and adaptability[1]. The evaluation of previous experiences in teaching laboratories shows the necessity to create a new teaching method that engages the students in the active learning process with a hands-on approach[2]. The CLABS (read as C-LABS) project, an initiative of the University of Houston's College of Technology, is an outgrowth of student and faculty opinions to design learning-centered instructional tools which would increase student engagement and address the unique requirements of stand-alone laboratory instruction. This paper will present our approach to laboratory practices and resulting performance improvements in our Computer Engineering Technology students' skills and learning experiences.

Introduction

With dynamic and competitive global market, graduating students need to have the ability to be creative in their approach to software and hardware problems and adapt to market needs. Therefore, being able to solve new problems based on the knowledge acquired has become a desired outcome of higher-education institutes. However, science, technology, engineering, and mathematics (STEM) education will reach this goal only when the education is engaging, interactive and delivers a set of leadership, teamwork, problem solving, analytical thinking, and communication skills.

Since laboratory teaching plays an important role in engineering technology education, it should have special attention and contribute to the development of the stated skills in student professional development. There is a consensus that traditional "cook book" style laboratory manuals does not contribute effectively to the development of the needed skills for student to be creative and analytical in solving problems. There is a need to develop engaging laboratory experience with problem solving emphasis and various skill and knowledge acquisition.

The authors at the Computer Engineering Technology (CETE) Program at the University of Houston have developed a set of laboratory experiments for the freshman and sophomore level courses with the following objectives: **(i)** active and hands-on student engagement to develop excellent problem solving and troubleshooting skills; **(ii)** provide opportunities for the students to develop teamwork skills; and **(iii)** encourage lifelong curiosity towards science and technology by establishing a just-in-time learning environment[3] with project-based materials, instruction, and research emphasis.

The objectives of this project are listed:

1. Laboratories should culminate towards a project, namely, an end product.
2. Experimental, computational, simulation, testing, teamwork, and communication skills should be gained through varying educational practices in laboratory instruction.
3. Active student engagement should be enhanced to increase curiosity and research aptitude.
4. Design and troubleshooting practices should be integrated to nurture creativity and innovation.
5. The instructional methods should span learning styles of diverse body of students to raise strengths of each individual learner.

This paper presents laboratory teaching model developed within the CLAB project to revamp the undergraduate laboratory education at the computer engineering technology program. It presents the model and gives an example of the AC/DC laboratory developed at the freshman level. The paper also highlights students' feedback and assessment for continuous improvement. The last section summarizes conclusions and lessons learned throughout the teaching of the laboratory with the new model.

Experiment Model

The main motivation in the CLABS lab experiment model, as shown in Figure 1, is to create a lab experience that engages the student in the active learning process through creative lab activities with special attention to cognitive processes. The educational activities listed below are derived from the cognitive process of Bloom's Taxonomy[4]: knowledge, comprehension, application, analysis, synthesis, and evaluation. Each lab experiment has the following components:

1. *Objectives*: Specific expected outcomes.
2. *Introduction*: Brief introduction.
3. *Pre-lab*: Before the lab session, where applicable, simulation and creation of electrical circuit diagrams, calculation and verification of parameter values.
4. *Parts list and equipment*.
5. *Experiment Body*: Implementation and testing procedures.
6. *Application*: Real-life example related to the main concept of that experiment.
7. *Conclusion*: Analysis.
8. *Report*: Experimental data and simulations, results and knowledge evaluation.

The experimental lab model is linked to the educational objectives of the ABET TC2K (Technology Criteria 2000) as outlined in Figure 1. The Objectives, Introduction, Pre-Lab and Parts List and Equipment conform to the Knowledge and Comprehension section of the experimental lab model. In this section, the team of students are introduced to the laboratory.

The teams consist of two students where students choose their own partners. This part of the experiment is simulation and calculation intensive in which tools such as PSpice, LabView or MultiSim are used by the student to discover and verify expected results.

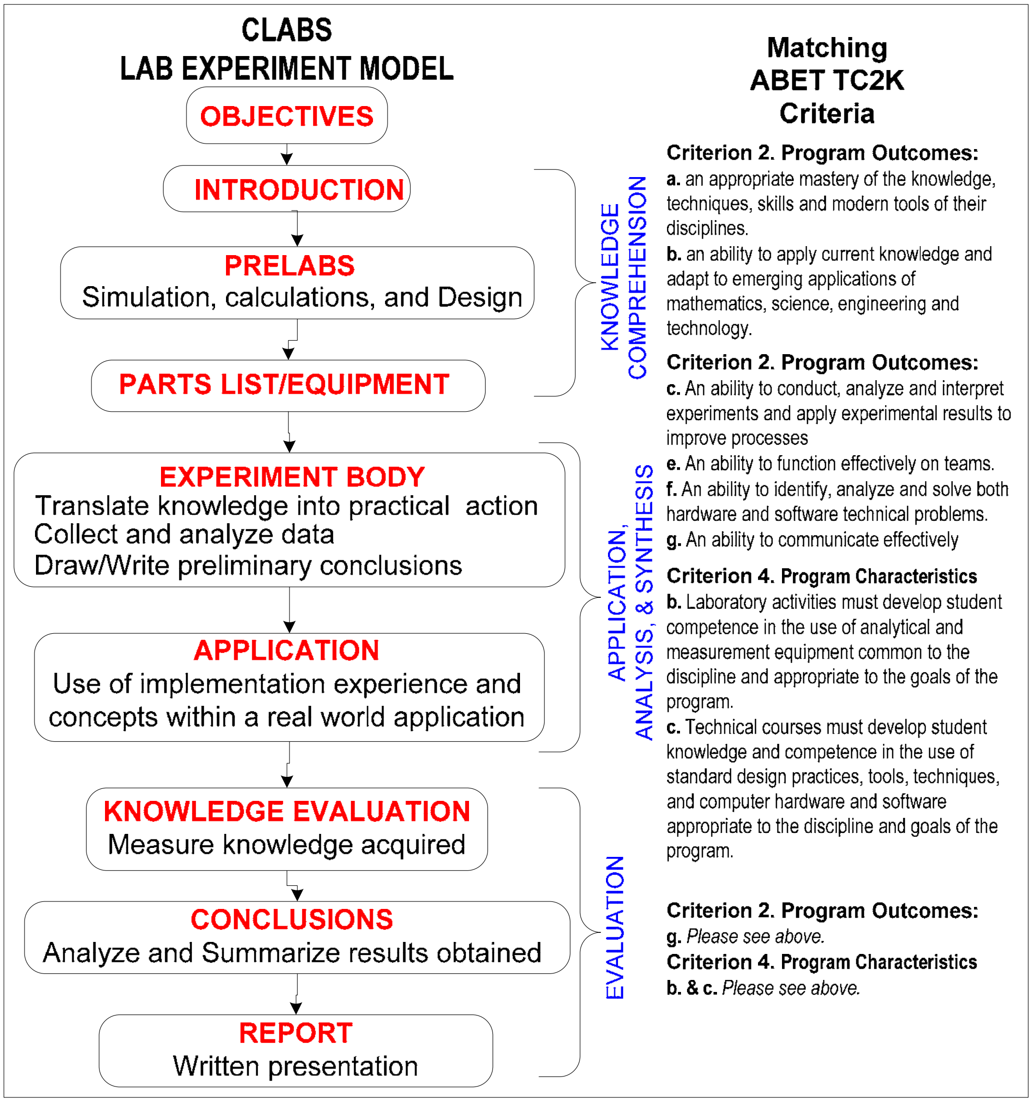

Figure 1. CLABS lab experiment model, matching educational components, and ABET TC2K learning outcomes

Once the simulations and calculations have been completed, the team is asked to implement a series of hands-on procedures that go from basic to complex and lead to a final application. During the procedure section, the team constructs electronic circuits simulated in the previous Pre-Lab section. The students then compare the obtained results from the procedures with the results obtained in the simulations and draw conclusions. These conclusions are recorded in pre-designed worksheets that are to be turned in and graded according to knowledge comprehension, quality and validity of the results. Finally, the student is presented with a real-life project, the Application in which he/she finds rationale behind the knowledge learned and reinforces the lessons learned in all the previous sections.

Upon completion of the Application, the team's work is ready to be evaluated. A series of Knowledge-based questions are asked to test the team's comprehension of the laboratory activity. In addition, teams are required to provide a formal report that includes their findings in addition to the result of the simulations, calculations, data verification and comparisons through concrete evidence such as graphs and mathematical analysis, circuit and logical diagrams, and conclusions.

At the end of the semester, a complex project is introduced where teams apply everything they have learned during the semester. The results of this project are to be presented in a formal report, a prototype and through a presentation given in front of their peers, lab assistants, lab managers, faculty in charge and invited faculty, and other guests. Every team's project is evaluated by everyone present in the presentation and the top three teams are selected and subsequently rewarded and recognized.

Completed Work

CLABS is an ongoing effort in CETE. As of the Spring semester 2006, the CLABS team has produced two freshman-level electronic labs, Electronic Circuits I and II, and one sophomore-level lab, Digital Circuits and Systems. These laboratories have been tested in pilot classes prior to their full deployment. The pilot testing has been useful to align the implementation with the educational objectives. In this respect, in addition to faculty observations, opinions, and feedback, interviews, mid-semester and end-of-semester student perception surveys were conducted. Formative assessment is embedded into the implementation practices of new instructional materials for seamless continuous improvement during the full deployments in the subsequent semesters. Table 1 shows a result of a student perception of a pilot section and other sections on the new lab materials and experiences.

Table 1. Student perceptions in the pilot section and other sections on the new lab materials and experiences.

Opinions	**Pilot Sections**		**Other Sections**
	Mid-semester	**End-of-semester**	
Gaining new skills	17% neutral	100% positive	N/A
Increasing practical knowledge	67% positive	100% positive	38% positive
New practical applications	50% positive	100% positive	40% positive
Pre-labs: Good preparation for the lab	41% positive	92% positive	N/A

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Project Example: DC Power Supply

A two week-long project has been developed for the Electrical Circuits I lab. The objective of the project is to build a power supply that converts 120Vac to 5Vdc. In the Introduction, the student is presented to the project at hand. The project has been divided into sections that the student must complete to obtain the final product. The power supply consists of:

1. The 120Vac-to-15Vac transformer (provided).
2. The full-wave rectifier.
3. The filters.
4. The voltage regulator.

The Figure 2 shows the block diagram of the power supply development steps as well as a visual representation of the gradual conversion from AC to DC.

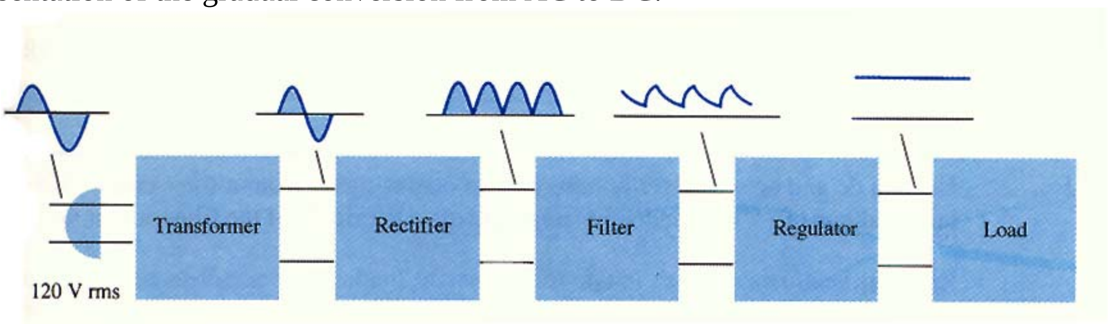


Figure 2. Power supply block diagram

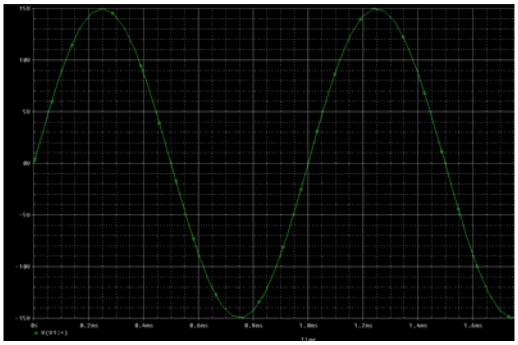
The first part of the power supply development begins when the student is introduced to the new components such as full-wave rectifier and voltage regulator, which are to be used in the power supply circuit. They run PSpice simulations to obtain the diode characteristic curve (forward and reverse bias characteristics), half-wave rectification and full-wave rectification. The full-wave rectifier is used in the actual circuit they are going to build in the first procedure. After they build the full-wave rectifier circuit, they are asked to compare their results with the simulated results and draw conclusions. An analysis leads to conclude that filtering and regulator circuits need to be subjected to the rectification circuit in order to produce DC. At this stage, they must solder the components to a pc board and test the circuit output (Figure 3).

Figure 3. Students performing soldering on a PCB.

In the second part of the project, each team is asked to take the previous simulated full-wave rectifier circuit simulated in PSpice and connect filter and regulation circuits. The pictures captured in the simulation are shown in the Figure 4.

The components such as rectifier, voltage regulator and transformer are not covered in depth but are introduced here to keep the students curious and look forward to the subsequent laboratories.

At the end of total experience students are made aware of their purposes in the power supply circuit.



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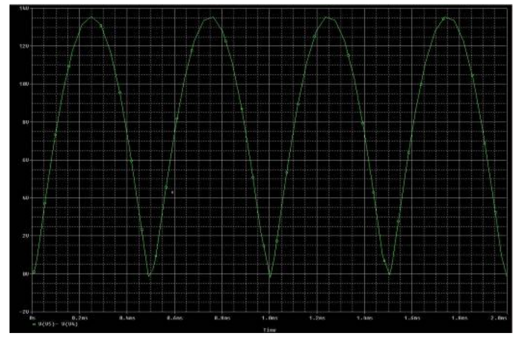

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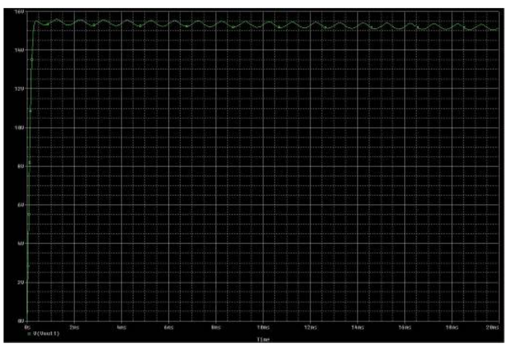

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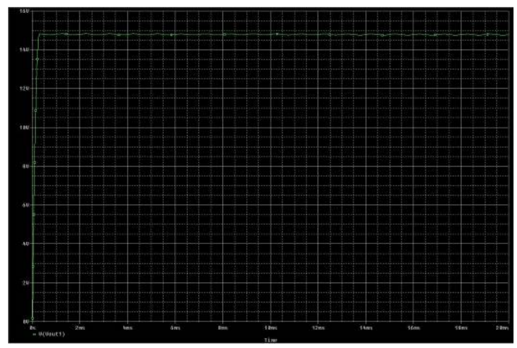

d)

Figure 4. Power supply output gradual conversion from AC to DC: a) AC input taken directly from the transformer. b) output in rectifier bridge. c) output taken after the filtering section. d) output after the regulator

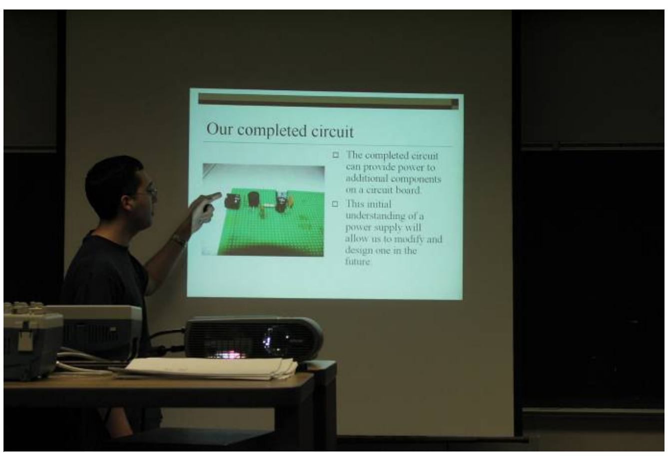

Figure 5. Students present their projects.

Students proceed to solder the filtering and regulator circuits and test their circuits. For the regulator circuit, a Fairchild KA78XX voltage regulator is provided. The students understand how a regulator circuit works in the simulation and realize that an integrated circuit exist that does the job as well or better. By studying the characteristics of the integrated circuit in the regulator's data sheet, they learned to make the necessary adjustment to the initially planned power supply to compensate for the IC.

After completion of the project, the teams write a formal report with all of their findings and conclusions and prepare for their presentations and demonstrations (Figure 5). At the presentation, each team is evaluated by everyone present in the lab. The best three teams are awarded.

Summary and Conclusions

The goal of the CLABS project is to design, implement, and continuously assess the core laboratories within a framework that promotes skill enhancement, creativity, critical thinking, research, and teamwork. The laboratory materials are expected to replace the current teaching materials. We are confident that this framework will improve the learning experience in engineering technology. We have been observing an increase in the skill set of our students after taking the improved laboratories. Our future work includes the revamping of all of the labs in the degree program with emphasis on the outlined methods of teaching. We are also developing a method for tracking the students as they progress through the degree program.

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