

**AC 2007-833: MOTIVATING STUDENT EFFORT IN ELECTRONICS BY
WORKING WITH PROJECTS OF PERSONAL INTEREST**

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Motivating Student Effort in Electronics by Working with Projects of Personal Interest

Abstract

Students majoring in electrical and computer engineering are required during their Junior year to take a three-hour lecture course and a two-credit-hour lab course in analog electronics. By the end of the course, students learn the theory and application of such components as diodes, Zener diodes, NPN and PNP transistors, MOSFETs, SCR's Diacs, Triacs, and optoelectronic devices.

This project investigated the effects on the student's learning of electronic concepts and applications by having them work on electronic projects which they specifically liked and enjoyed, and then compared these results to the traditional projects required by the curricula. Students worked on several learning oriented, pre-defined labs and then on an electronic project of their own choosing. The project involved using electronic components studied during the course applied to devices the students were personally interested in; for example, electrical guitar audio amplifier circuits or electronic race-car control systems.

At the end of the semester, a survey was given to measure and determine the results on student learning concerning the concepts and applications of electronics. The survey was aimed to discover the development of mental skills in the cognitive domain, by comparing the results of the projects which the students chose with those that had been already required for their curricula. The results of this project may encourage educators to develop laboratory curricula that are interesting, enjoyable, and enhance student learning.

Introduction

Students majoring in electrical and computer engineering are required during their Junior year to take a three-hour lecture course and a two-credit-hour lab course in analog electronics. The content of the three hour lecture course is organized in six to seven topics that cover the following subjects:

1. Diodes and Rectifiers
2. Semiconductor Physics
3. Two-Ports, Load Lines and Biasing
4. Piecewise-Linear Models
5. Q-Point Stabilization, Thermal and Environmental Considerations
6. Emitter Follower, Common Base and Common Emitter, Coupling and Loading
7. Power Amplifier, Transformer Coupling
8. Operational Amplifiers
9. N and P channel depletion and enhancement MOSFET

To provide the students with an enhanced hands-on experience of the electronic components studied in their lectures, a set of 12 learning oriented, pre-defined labs are incorporated in a two hour lab course. These labs cover the following topics:

1. Introduction to diode circuits (terminal characteristic of simple rectifier circuits)

2. Diode circuits I-V curves of diodes (series and parallel circuits) and I-V curves of zener diode circuits.
3. Diode circuit applications in clippers, clampers, DC filters and regulator circuits.
4. Passive and active, low pass and high pass filters.
5. RLC resonant circuit response and Characteristics.
6. Introduction to terminal characteristic of BJT transistors (DC load lines and Q points)
7. BJT transistors and small signal amplification (DC and AC load lines)
8. BJT transistor's thermal stability and frequency response.
9. Type C operation of BJT Transistors: LC oscillator and frequency multiplier.
10. Applications of Operational Amplifiers.
11. Introduction to terminal characteristic of MOSFET transistors (DC and AC analysis).

By the end of the semester, students have theoretical knowledge of, and application experience with components such as diodes, Zener diodes, NPN and PNP transistors, operational amplifiers, LPF, HPF and BPF, MOSFETs, SCR's Diacs, Triacs, and optoelectronic devices.

Background

In 1948 a group of educational psychologists lead by Bloom, formulated a classification of the goals of the educational process. This became what is commonly known as Bloom's taxonomy. Three domains of educational activities were identified: the cognitive domain, the affective domain and the psychomotor domain.^{1,2} The cognitive domain deals with knowledge and the development of intellectual skills. The cognitive domain consisted of 6 levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. The lectures and the lab experiments engaged the majority of the students up to level 3 of cognitive domain (knowledge, comprehension and application). We wanted to provide the students with a challenge to help them develop thinking skills of the higher levels (analysis, synthesis and evaluation).^{3,4,5}

Motivation is a key element in student learning and persistence. Motivated students "exhibit effort on tasks, persist under difficult circumstances, and maintain positive beliefs about (their) academic abilities."⁶ Ideally, the motivation is intrinsic motivation, generated internally from a desire to learn, rather than external motivation, generated by external rewards (or punishments).⁷ "Intrinsic motivation can be enhanced by providing students with learning which is challenging, which engages curiosity, where they have a degree of control and where there is a game-like or fantasy dimension."⁸ We have found that engineering students are most highly motivated to tackle new material when it seems relevant, when it corresponds to things they already know, and when they are already interested in the material or the results of the skills they will learn.

Students were provided with the challenge to work on electronic projects which they specifically liked and were interested in, and then compared their learning experience to the traditional pre-defined projects required by the curricula. This new electronic project was introduced in the fall semester of 2006 and had the following objectives:

1. Provide students with the opportunity to apply the concepts learned from the lectures and the instructor's predefined labs.

2. Allow students to work on projects that motivate them.
3. Provide a fun and enjoyable problem solving real life learning experience
4. Engage the students in the analysis, synthesis and evaluation process to generate a working solution for their projects

Methodology

Students were asked to perform the following tasks:

1. After the second week, students were asked to choose an electronic project meeting the following two conditions:

A project which they specifically like or of personal interest and would enjoy doing it. A project in which they use the electronic components studied during the course.

Knowing what they like and understanding the principles of the electronic components at hand, they each selected an individual project.

2. During the third week, students were asked to do the following:

To form groups of four, discuss each project idea, and select one out of the four projects. Briefly describe a tentative solution to the project selected, and define the project scope and objectives. Following is a brief definition of the projects turned in:

- An electronic salinity tester. The solution proposed for this project was to use an op-amp comparator circuit and control of the resistance of the solution with changes in salt concentration.
- An electronic voice equalizer system. The solution proposed for this project was to use their knowledge of filtering and amplification to equalize a voice signal.
- An electronic voice modulator. The solution proposed for this project was to use their knowledge of amplifiers and signal mixers to generate sound effects and to human voice signals.
- An electronic musical tuner. The solution proposed for this project was to apply their knowledge of impedances, frequency and impedance at resonance in RLC circuits to tune a musical instrument.

After turning in the tentative solutions to the projects, the students were required to start a literature review of the proposed solution, to investigate, and to understand the existing research that was significant to their project problem.

3. At the beginning of the fifth week, the students were asked to perform the following tasks:

- 1) Discuss among the members of their group the findings of the literature review and look for ways to improve or implement an alternative solution in addition to the existing solutions.
 - 2) Redefine the design of the project, its scope and objectives
 - 3) Write down an action plan defining the responsibilities of each member: final design, drawings, implementation, testing procedures, design corrections, result gathering, report writing and power point presentations.
4. From the sixth to the tenth week, students had time to work on the implementation of their projects.
5. During the eighth week, one group gave a public presentation of its project to a group of visiting students and their families during one of the school's scheduled events for new prospective students, the "school's recruiting, preview weekends".

From the tenth to eleventh week the rest of the student groups gave their in-class project's power point presentations.

Challenges and Opportunities

As a result of guiding the students through the process of conception, development, and implementation of their projects, different stages of learning and application of knowledge can be observed. Following is a brief description of this process:

1. The electronic salinity tester

The preliminary design consisted of a pair of probes connected to the input terminals of a differential-operational amplifier with its output terminal connected to a set of LEDs diodes.

Problems and challenges that provided opportunities for learning:

- Surface area, type of material of the probe, and the distance between the probes gave different values of resistance and output voltage levels.
- The need for a mathematical equation to relate the output voltage to the salt concentration level.
- No sufficient voltage amplification to distinguish between different salt concentration levels.
- Time taken by the solution to reach a settlement state to produce a fairly constant value.

The final design consisted of the pair of probes that provided the best output voltage levels, connected to a differential-operational amplifier followed by a circuit array to interface it with a HC12 microcontroller. The HC12 read the different voltage levels, applied the mathematical equation developed, and as a result generated the solution's salt concentration level.

2. The electronic equalizer system

The first attempted solution was to use three filters: a low pass filter “LPF”, band pass filter “BPF”, and a high pass filter “HPF” combined into a summing amplifier circuit; this, in turn, to create a 3 band equalizer of voice signals in the range of 80Hz to 800 Hz.

Problems and challenges that provided opportunities for learning:

- Circuit board, wiring connections and improper grounding
- Troubleshooting of defective components
- Poor performance of design configuration
- Selection of appropriate technology (use of passive or active filters)

The final design consisted of four filters: a low pass filter, two band pass filters and a high pass filter combined into a summing amplifier, to create a four band equalizer of voice signals that performed as students expected in the range of 80Hz to 800Hz.

3. The electronic voice modulator

The preliminary solution proposed for this project was to use a pre-amplifier circuit to boost the signal received from a microphone and combine it in a mixer circuit with different frequency signals to generate and add effects to the human voice.

Problems and challenges that provided opportunities for learning:

- Selection of the proper mixing circuit (linear mixing, non linear transistor circuit, non linear ring modulator circuit)
- Improper amplification (over-voltage or low current amplification)
- Proper selection of the oscillator’s multiple frequencies.
- Poor wire connections, loading and improper grounding.

The final design consisted of a microphone connected to a pre-amplifier circuit followed by a diode ring modulator circuit that combined the input frequency with signals from a 555 timer oscillator circuit. The modulated signal coming out of the modulator circuit was connected to an amplifier circuit and finally connected to a speaker. The voice modulator was able to generate a normal voice when off, an alien voice, a robot like voice, a ghost like voice and a cartoon high pitch voice (the students were unable to generate the last two voice effects due to wiring problems).

4. The electronic musical tuner

The preliminary proposal for this project was to tune an electrical guitar using the A string (110 HZ) to tune it. The proposal included an amplifier circuit to receive the signal from the electrical guitar and output the signal to a RLC circuit. Each circuit element of the RLC circuit was connected to a diode circuit to signal if the string was tuned. If the

string was tuned, the LED connected to Vr was light, if the string was flat, the LED connected to Vc was light, and if the string was sharp the LED connected to Vl was light.

Problems and challenges that provided opportunities for learning:

- Wiring problems and improper grounding
- Weak signals and poor amplification
- Improper design configuration (LED output circuit)

The students were not able to finish their design.

Results

At the end of the semester, an anonymous survey was given to measure and determine the results on student learning concerning the concepts and applications of electronics. An analysis of the results of each of the questions of the survey is given:

1. Has the use of diodes in your project improved your understanding of diodes and their applications?

Definitely false	12.5%	Mostly false	0%	Neutral	12.5%	Mostly true	25%	Definitely true	50%
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50% of the students in the course responded that the use of diodes in their projects helped them in their understanding and application of diodes. The 12.5% that responded definitely false must have misunderstood the question, for this is the only instance in which this percent occurs in the entire survey.

2. Has the use of transistors in your project improved your understanding of transistors and their applications?

Definitely false	0%	Mostly false	0%	Neutral	0%	Mostly true	25%	Definitely true	75%
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The majority of the students responded that the use of transistor in their projects helped them in the understanding of transistors and their applications.

3. Has the use of Mosfets in your project improved your understanding of Mosfets and their applications?

Definitely false	0%	Mostly false	0%	Neutral	0%	Mostly true	0%	Definitely true	0%
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None of the students used MOSFETs in their projects.

4. Has the use of LICs in your project improved your understanding of LICs and their applications?

Definitely false	0%	Mostly false	0%	Neutral	11%	Mostly true	67%	Definitely true	22%
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Once again the majority of the students responded positively, 67% mostly true and 22 % definitely true.

5. Has the use of any other electronic component in your project improved your understanding of the component and their applications?

Definitely false	0%	Mostly false	0%	Neutral	8.3%	Mostly true	66.7%	Definitely true	25%
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The majority of the responses are positive.

6. Has the course's regular diode lab improved your understanding of diodes and their applications?

Definitely false	0%	Mostly false	0%	Neutral	0%	Mostly true	23%	Definitely true	77%
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It is important to notice that the majority of students responded (77% definitely true, 23% mostly true) that the traditional pre-defined labs helped them versus those (25% definitely true, 75% mostly true) that responded that the projects helped them.

7. Has the course's regular transistor lab improved your understanding of diodes and their applications?

Definitely false	0%	Mostly false	0%	Neutral	0%	Mostly true	54%	Definitely true	46%
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It is important to notice that that the majority of students responded (54% mostly true, 46% definitely true) that the traditional pre-defined labs helped them versus those (25% mostly true, 75% definitely true) that responded that the project helped them.

8. Has the course's regular MOSFET lab improved your understanding of diodes and their applications?

Definitely false	0%	Mostly false	0%	Neutral	30.7%	Mostly true	38.6%	Definitely true	30.7%
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Even though the majority (38.6% mostly true, 30.7% definitely true) still responded positively there is a large percentage of students (30.7% neutral) that responded neutral. This might have influenced the students not to work with MOSFETs in their projects.

Conclusions

The traditional pre-defined diode labs are achieving their goal of providing a greater learning experience of diodes and their applications, as opposed to the pre-defined transistor-circuit labs which simply provide the basic foundation. The results of the survey suggest that the learning process is greatly enhanced by real life applications such as the student's projects.

The predefined MOSFET labs must be revised to provide a greater learning experience of the concepts and applications of MOSFET s. Having the students choose an electronic project in which they had personal interest motivated their efforts to learn electronics.

The project provided the means for the students to recall the acquired “knowledge” from the lectures and pre-defined labs.

They were able to “comprehend”, understand, and recognize what was needed and required to complete the project.

They were able to “apply” or had the ability to use their acquired knowledge to the design and implementation of the project.

They were able to “analyze” examine, break the solution into components, identify its parts and relationships, and recognize the applied principles.

They were able to formulate, design, and assemble a new solution combining their existing knowledge and experiences (“Synthesis”).

They were able to “evaluate”, compare, argue and select their design ideas, designs, solutions, results, and conclusions.

The students were able to move from the basic transfer of facts and knowledge (lower levels of the cognitive domain), to the higher levels of thinking skills, in which they were able to analyze, formulate and evaluate different solutions and ideas to finally deliver a working module. The implication of this result is important for all of us who teach, since we want to promote in our students the development of higher level thinking skills and the mastery of the subjects we teach. Another important factor that contributed to the success of the projects was the level of motivation of the students. The students were engaged by the challenge and the opportunity to work in projects of their personal interest.

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