A Curriculum Design on Electronic Devices Design Laboratory

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Abstract*— In this paper, a curriculum has been modified to foster the learning processes associated with the learning objectives of Electronic Devices Design Laboratory. Facilitating the integration of content, assessment, and pedagogy for this learning module can be accomplished by first thinking about the requirements and learning objectives of this laboratory course and then, finding metrics that measure the mastery of them and finally discovering approaches to teach those learning objectives to the learners. The main goal of this course is to help the students learn how to work as a team in order to design and simulate electronic circuits. Moreover, the students will learn how to transmit information in an accurate, objective and complete way. In this paper, learning objectives and enduring outcomes for Electronic Devices Design Laboratory Course are detected, and based on the goals of the course, assessment worksheets are developed, and finally the structure of a lab session is presented.

Keywords*— Content, Assessment, Electronic Devices Lab, Pedagogy

I. INTRODUCTION

The Electronic Devices Design Laboratory was designed in 80s and it has been revised for more than ten times since then. Although, the experiments have been designed efficiently, it seems that the students are not fully involved in the content of the course. In fact, as the instructor of the course, it has been observed that the majority of the learners care about just doing the required tasks in order to submit the reports for the sake of grades. The main issue with the status quo is amount of required tasks. Therefore, the students will not be able to analyze the results and trouble shoot their circuit design on their own in the lab session. Oftentimes, students repeat what the instructor asks them to do. However, the overwhelming amount of tasks do not provide enough time for them to think and find the solutions for the problems.

The curriculum in this paper is being developed as part of the Bachelor of Science in Electrical and Computer Engineering program at Purdue University. The course is a 200-level course mainly taken by sophomore students. The learners will be able to predict the behavior of the electric circuits using simulation software and compare the simulated results with the actual data obtained from their constructed circuits. In this revised version of the Electronic Devices Design Laboratory, the authors have tried to increase the learners' motivation and to give them more chances to identify and solve the problems by presenting common challenges in electronic circuit design in industry. The authors monitored the performance of the students to identify their mistakes and to recognize the challenging parts of the experiments. In the next section, the authors elaborate on the contents and learning objectives of this curriculum design. Next, the assessments for the three main learning objectives will be discussed, and finally, the pedagogy will be thoroughly described to the audience.

II. CONTENT

Among the required courses in the Electrical Engineering Bachelor of Science program, there are some courses which significantly are more critical in providing contents to students. Such courses help learners deeply understand the major concepts associated with the field of Electrical Engineering. The course designed by the authors of this paper is significantly beneficial for the students in teaching them how to work as a team, writing an engineering report, implementing ideas of electronic circuits, and more importantly designing a lab session based on the skill and knowledge gained throughout the semester. Not only do the students learn how to choose proper equations and solve them to find different variables, but also it is necessary for them to obtain the graphical, simulation, and writing skills.

This is essential to identify the enduring outcomes prior to initiate designing a course. The enduring outcomes are the concepts, designs, attitudes, and outlook that constitute the united learning needed by the students. Therefore, the learners in this course are expected to familiarize and maintain these contents and apply those in the future and set up and elaborate the obtained knowledge for the advanced level courses.

Besides the enduring outcomes, there are other concepts and activities in this course that are important to know. What is the structure of an amplifier and attenuator? How to use digital multimeter to troubleshoot the circuit? Those all are extremely critical for an Electrical Engineer to learn and use in her future career. Knowing such ideas are beneficial for the learners in order to examine the robustness of the results.

In addition, there are additional contents that the learners should become familiar with. The concepts such as, bandwidth, calculating capacitor value based on the frequency and the required impedance, how to detect different leads of the

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elements, using Excel sheet to represent the data and plotting those, and soldering components on the board are all included in this category. Table I demonstrates, enduring outcomes (EO), important to know (IK), and good to be familiar with (GK) items for the learning objectives and the contents.

TABLE I. CURRICULAR PROPERTIES AND CONTENTS

CURRICULAR PROPERTIES	CONTENTS
EO1: It is essential for every engineer to be able to communicate the compiled information obtained from experiment or research.	Phases of writing a report: • Abstract • Objectives • Procedure • Results and discussion • Conclusion
EO2: Every element in the circuit must be biased on a specific point of operation. The range of current and voltage should be considered before designing any circuit.	• Feasibility of the calculated variables. • Compatibility of the simulation results with the calculated variables.
EO3: The concept of current-voltage plot	• Measuring impedance of the linear and nonlinear components based on I-V plot. • Investigating measurement tools. • Measuring threshold voltage of the diode from the I-V plot.
IK1: Structure of common electrical circuits for the purpose of amplification and attenuation of the signal.	• Investigating required components and position of input and output. • Calculating the gain.
IK2: Troubleshooting circuits using proper devices.	• Functionality of DMM and oscilloscope • Looking for the reasons that the circuit doesn't function
IK3: Using simulation soft-wares to investigate the behavior of the circuits.	• Validation of the results from actual circuit they have built by the electronics simulators software. • Predicting the behavior of the different circuits.
GK1: Finding bandwidth of different components and circuits.	• Using function generator and simulation software to investigate the frequency range of input signal processing.
GK2: Identifying the leads of electrical components.	• Set up a test set to identifying different leads of the electrical components.
GK3: Obtaining the skill of soldering	• Locate components properly • Investigating the quality of the soldered junctions.

The concept map (FIG. I) represents the three enduring concepts (in gray) and demonstrates the relationships between those enduring outcomes with important to know (in yellow) as well as good to be familiar with concepts (in green) - the same color codes sued in Table I (Curricular Properties). Writing scientific reports, biasing different components of the circuits, and plotting the I-V curve characteristics are presented at the top of the flow chart since these three goals form the basis of every subject in this course. Furthermore, in this curriculum design, it is essential to find the ratio of different variables to investigate linearity, finding impedances, and identifying thresholds of diodes. These goals can be accomplished by using I-V characteristics plots which can be obtained from an oscilloscope. More importantly, in order to make the circuit work, learners must calculate the proper values of current and voltages for different components of the circuits based on the well-known equations such as, KVL and KCL laws. The calculated values can be verified using LT-Spice software. Additionally, the learners can predict the behavior of the circuits before building those by employing simulation software (IK-3 in green). Troubleshooting the circuits results to check the accuracy of the pre-designed biasing points can be performed using the digital multimeter and oscilloscope.

In the Electrical Engineering curriculum, Electronics is perceived as a "tough" course which causes panic in students due to the fac that they encounter non-linear circuits and active components. This course makes a starting point for threshold concepts. Modeling the non-linear components such as, diodes and transistors, and dynamic resistance, and differentiation between weak signal and strong signal can be considered as the threshold concepts. The concept of analyzing the circuits in two approaches of DC and AC causes some misconceptions for the students as they think the analysis are separated. Hence, they try to build their actual circuit based on the modeling method and they forget to apply both AC and DC voltages simultaneously to the circuits.

According to the enduring outcome, I-V curve characteristics represents the relationship between current and voltage of linear and non-linear devices [1]. However, as the non-linear devices like diodes donot obey the Ohm's law, it causes the learners to use non-linear equations, which are tough for a majority of them. In order to simplify the equations, some linear models are defined for the non-linear components, however, substituting this model to a real scenario sometimes is not understandable for the learners. As an example: one can change the resistance of a diode by simply changing the amount of voltage applied to it. One can benefit from this property of the diode and make the circuits like attenuators with different gains. However, some of the students does not fully understand what to do in order to get different attenuation gains. Therefore, they manually put external resistor in the circuit. It takes time for the learners to fully comprehend the diode model and apply it in the real experiments.

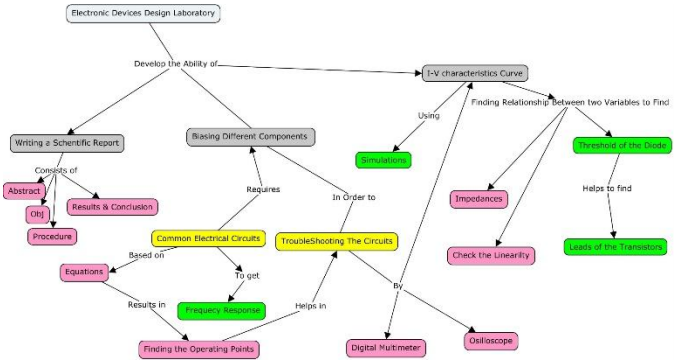

FIG I. CONCEPT MAP

III. ASSESSMENT

According to Svinicki [2], this is the student's job to learn the contents, and it is the instructor's role to make sure they do it. Assessment is a way to conduct the intention of teaching. Are we teaching what we are intended to teach? If not, is there a better way to teach the materials? The learning objectives for this course are presented in the following:

1. Use proper equations to relate voltage and current of the resistors, capacitors, diodes, and transistors of the circuit.

2. Choose appropriate values for each of the resistors, capacitors and power sources for a feasible desired point of operation of the circuit elements.
3. Recognize each element's role in the circuits.
4. Formulate output and input of the circuits using KVL and KCL rules or two different variables to investigate the relationship between them using I-V characteristics curve.
5. Write a report that consists of the objectives of each experiment which reflects the main ideas and goals, procedures and represents the results.
6. Analyze the results and conclude what it has been found during each experiment.
7. Summarize the main concepts of each experiment in the submitted report.
8. Recall the diagram of common well-known circuits such as current mirrors, common emitter amplifiers, comparator, rectifiers, differential amplifiers and Operational Amplifiers
9. Getting familiar with analog and digital multimeters, function generator and oscilloscope their functions and be able to use the proper measurement device in different situations.
10. Troubleshooting the circuit by employing appropriate tools and being able to find the starting spot of the circuit for this purpose.

Based on the above learning objectives, the bloom's taxonomy table is depicted in Table II:

TABLE II. REVISED BLOOM'S TAXONOMY [3]

Learning Objectives	The Cognitive Process Dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge				2_EO	7-EO	
Procedural Knowledge			10-IK 14-IK	4-EO 6-EO		5-EO
Metacognitive Knowledge						

To meet the goals of learning objectives, the authors have created an assessment worksheet for each of three learning objectives that measures mastery of enduring outcomes, difficult conceptions, misconceptions, or threshold concepts.

Learning Objective. Formulate output and input of the circuits using KVL and KCL rules or two different variables to investigate the relationship between them using I-V characteristics curve

Task: In some of the tasks of the experiments, the learners will be asked to capture X-Y mode graph by oscilloscope to measure impedances and finding the relationship between variables.

Furthermore, there are 4 online quizzes that the students should take regarding the main learning objectives of the previous experiments

Evidence: The learners should provide required graphs for their submitted report. The online quizzes should be completed in Blackboard. The quizzes contains 3 problems. First one is a true or false problem which is related to the lab manual and completed tasks.

Second problem usually is similar to the prelab questions and the last one is a calculation problem which the learners should calculate a variable in a circuit.

Acceptable Evidence: The learners should obtain a score of 80% or higher on the online quizzes. The simulation results should match with the captured graphs.

How these assessments meet the essential criteria for an authentic assessment? According to Hansen [4], there are 6 criteria for an authentic assessment. Here, the authors are investigating these criteria for the first assessment worksheet:

1. Be persuasively contextualized.

The students will be designing a lab session by beginning with the problem & solving approach. They need to come up with a topic and define what is the application and what is the problem they are trying to solve.

2. Require judgment and innovation.

The learners will decide what their approach is to solve the problem and what their procedure is to do this. They always can verify their method by using simulation software and can make judgments whether the chose approach is rational and capable.

3. Ask the students to "do" the subject.

The students will need to actually build their own circuit and testing it. They will provide the components by themselves and investigate the cost of the circuit and its efficiency.

4. The learners will encounter with the challenges of designing an experiment.

The designed tasks should be clear enough and fill a 3 hours class. Since they work as a team the learners can get feedbacks from their partners and apply it for their aims.

5. Assess the student's ability to use a repertoire of knowledge and skill.

Students will use their knowledge for picking proper values for different components. They use the skills of simulations and modifications of the circuits.

IV. PEDAGOGY

A. *Play the Whole Game*

This is the kick off session in Electronics Devices that the Electrical and Computer Engineering students take to be physically exposed to the new components in the field of Electronics. The non-linear elements, active and passive element, and multiport devices, are all new concepts that students have not experimented before. In this lab session, the instructor tries to involve learners with the new electrical components from the beginning of the class. Such components are the ones which learners will deal with those throughout the semester. In the first session of this course the students will be asked to randomly select an electrical component from the baskets. Each element has been labeled with A, B, or C. Besides, each of the students are assigned to either group A or B (Based on the skill sheet filled out before) so they should pick the symbols from the pre-assigned basket. Then, the students will be asked to make a circuit with all of the components they have picked, and based on the positions of the nodes, they will be assigned to the lab stations. The schematic figure of the activity is presented in FIG II.

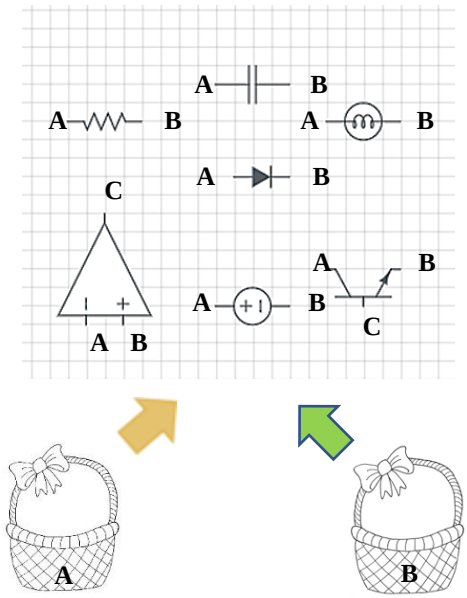

FIG II. FIRST SESSION ACITIVTY

In order to show the idea of the multi-terminal elements, a transistor and an op-amp (three terminal devices) has been placed in the basket. So, the learners that have the third terminals will be working together as a group. The groups of "A" s and "B" s has been distinguished based on the skills of the learners. The students should be complimentary of each other in mastering different skills. The student-made-circuit may not be theoretically working, however, the instructor can randomly pick some random values and use the simulation software to demonstrate the behavior of the circuit.

Throughout the semester, students will complete 12 different experiments regarding the I-V curve of different components, amplifiers and attenuators, Power MOSFETS, Operational and differential amplifiers and so on. 2 weeks will be dedicated to the midterm and final exam and one week is allocated to the lab design. The instructor is encouraged to use CMAP to demonstrate the important ideas of this unit and explain how different concepts can be related to each other.

B. Make the Game Worth Playing

The purpose of this curriculum design is to introduce students to materials in the electronics area. The learners take the fundamental concepts of non-linear devices and multi-port elements of electrical components. The learners get familiar with the challenges and concerns they would face in the process of circuit design such as, picking proper values for elements, choosing appropriate equations to find relationships between different variables, using graphs to find the impedances, and/or distinguishing different leads of multiport devices. They also use simulation software to investigate the functionality of their circuits. Students will be given the history of the new components and the benefits of having such a device in today's real circuits. Such examples serve as an important motivator for the learners since they can apply their experiments in real life, and they feel the need of those concepts in the real circuit design for the appliances.

C. Work on Hard Parts

It is essential for the instructor to predict the hard parts prior to the experiments and find suitable approaches to facilitate learning those concepts for the students. The first thing that learners find hard is the concept of voltage probes of oscilloscopes due to the reason that they cannot directly measure the current using a voltage probe. To measure the current of an element, they need to use an auxiliary device called "Diff-Amp" which prevents the elements from being shorted in circuits. This is the first time they encounter a Diff-Amp, hence, some of them struggle with finding the correct set up.

D. Play Out of Town

A fundamental skill in teaching is finding an approach to transfer knowledge to the learners. One of the approaches in fostering learning is providing slides containing the materials of the syllabus in the form of images and attractive images. Streaming short online videos and making fancy slides seem to be effective in absorbing attention and conveying the lectures' contents.

E. Uncover the Hidden Game

Students submit their prelab questions at the beginning of the lab sessions. The questions are all about the upcoming experiment that deal with the calculation of the value of variables or deal with finding a method to perform an experiment. Although it may be true that the learners should be motivated to ask questions, however, in many cases they are reluctant to do that. The authors believe that by making the task as an assignment, the learners will ask the questions and think more deeply on the solutions before submitting them.

V. CONCLUSION

The main goal of this course is to help the students learn how to work as a team in order to design and simulate electronic circuits. This course is being developed as part of the Bachelor of Science in Electrical and Computer Engineering program at Purdue University. The course is a 200-level course mainly taken by sophomore students. The main leaning objectives for this course are finding impedances, threshold voltage of the diodes and leads of the transistors and investigating the linearity of electronic components by employing X-Y mode of the oscilloscope. Furthermore, the learners will be able to predict the behavior of the electric circuits using simulation software and compare the simulated results with the actual data obtained from their constructed circuits. Besides, presenting the results of experiments and researches and analyzing the data is essential for the learners since the real value of an experiment and research can be assessed through the reports. For this purpose, in this course, the students will learn how to transmit information in an accurate, objective and complete way. To satisfy the learning objective needs, a certain set of experiments and tasks has been designed. The learners are asked to answer to the Prelab questions and perform the tasks during the class time. The instructor will give the students feedback and comments for the reports. Furthermore, each class starts with discussing about common mistakes of previous experiments, and also hard things and important concepts to remember.

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