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Flipping the Biomedical Engineering Classroom: Implementation and Assessment in Medical Electronics Course

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Flipping the Biomedical Engineering Classroom
Implementation and Assessment in Medical Electronics Course (Work in Progress)

Background:

The flipped classroom paradigm inverts the traditional “teaching/lecture – learning/homework” model by delivering the instruction online outside of classroom and placing the active part of the instruction, the “homework” into the classroom. Typically, the learning content is delivered through recorded lecture videos, by the students reading short articles, visiting websites, and other modes of content delivery. Application of the lecture content is done in the classroom usually in small groups in the form of problem solving, laboratory activities (virtual or physical), group learning etc. with guidance by the instructor. The flipped classroom paradigm was first introduced 2007 for teaching high school science (1, 2) but has since attracted science and engineering instructors in universities and colleges (3, 4). Among its main benefits, the flipped classroom enables students to receive the most support when they are working on the most cognitively demanding tasks. The flipped classroom increases interaction between instructor and student and between student and student. This is beneficial since peer teaching is thought to greatly enhance learning. The students learn to work in teams as most will do in their professional life. The students are made responsible learners in charge of their own learning and can receive individualized instruction to remediate weaknesses or misconceptions. The students can view the video lectures multiple times, which can benefit those who struggle with the material. Students do not miss presentation of the lecture material due to illness or absences. The classroom environment is more dynamic, lively, and focused on the application of the material learned in the video lectures. There is more time in the classroom to work on complex problems including simulations and open-ended real-life or simulated design exercises.

The flipped classroom paradigm is being implemented in “Medical Electronics”, a required course within our undergraduate curriculum. Approximately 50 engineering students, juniors and seniors, enroll in this semester-long course every year. The goal of the course is to introduce students to the analysis and design of analog electronic circuits at the core of biomedical instruments. The students learn about essential functions such as signal sensing, direct current (dc) power generation, signal amplification, and conditioning, and about the electronic components used to implement these functions: bio-transducers, diodes, transistors, and operational amplifiers.

The course learning objectives include: 1) the ability to explain the operation of bio-transducers (electrodes, thermistors, strain gages), diodes, transistors, and operational amplifiers; 2) the ability to analyze and design linear dc power supplies, signal amplifiers, electronic filters, and comparators; 3) the ability to assemble, test, and troubleshoot in the laboratory hardware circuits that implement these functions; and 4) the ability to interact cooperatively within a student team working on laboratory circuits and a project. The subject matter requires understanding the theoretical operation of electronic components and learning how to analyze and design fundamental circuits built with these components. The skills required for circuit analysis and design are essential to learning the subject matter, which implies systematic practice on exercises where students analyze or design electronic circuits.

Prior to adopting the flipped classroom approach, the classroom activities comprised short lecture segments presented with Powerpoint presentations interspersed with application exercises called "activities" in which the students worked alone or in groups of two to analyze an electronic circuit related to the preceding lecture segment. Occasionally, the activity used the circuit simulation software "Multisim" that allowed the students to conduct virtual experiments in which they built and tested simulated circuits, or experimented with a faulty component, to visualize and understand how the fault affects circuit behavior. During the activities, the instructor walked in the classroom to help the students unable to complete the activity on their own and gage the group's understanding of the content application presented in the activity. When it appeared that a majority of students had completed the activity, a formal solution was presented to the class; students' questions were answered and the next lecture segment was presented. The lecture segments and activities each comprised approximately 50% of the classroom time. Changing to the flipped classroom approach represents an evolution of the prior approach in which the lecture content is moved outside of the classroom and ahead of the activities which now represent the bulk of the in-class work.

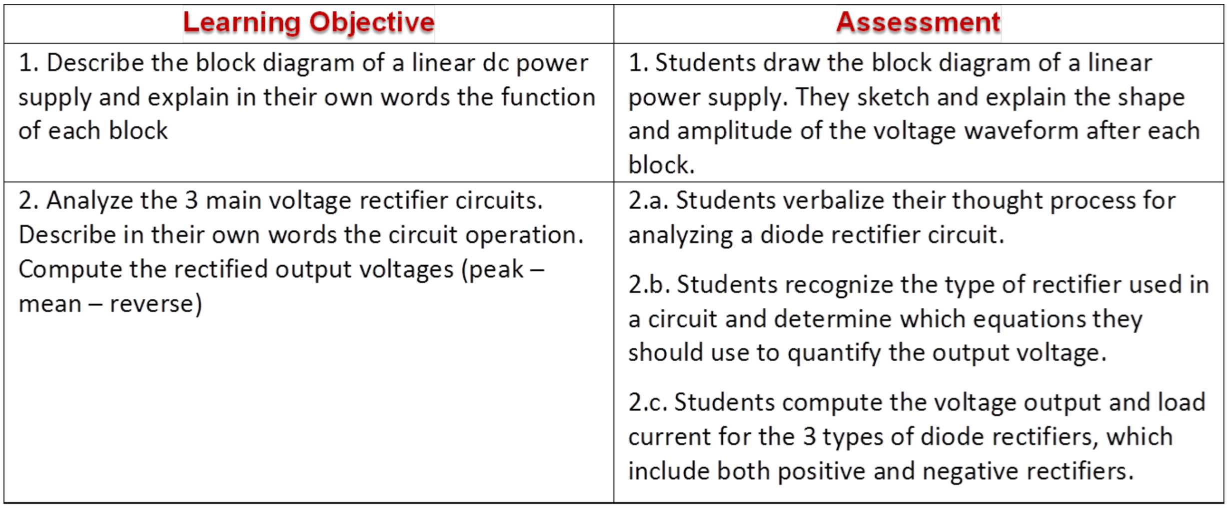
Implementation of online content for flipping the "Medical Electronics" course:

The implementation plan called for first, designing and developing the online video lessons and posting them on the learning management system "Blackboard". The online lessons are watched by the students prior coming to class and include a few sample practice problems for the students to practice application of the lesson material to solve circuit analysis exercises. The students prepare one or more questions to bring to class. Second, in the classroom the instructor and the students address some of the students' questions. The students then engage in group activities centered on circuit analysis and design problems and virtual laboratory exercises using the simulation software "Multisim".

Design of learning content and assessment approach:

The backwards design approach is applied to design the learning content. In this approach, the content designer first defines "SMART" learning objectives for each lesson, in which SMART is an acronym for <u>S</u>pecific, <u>M</u>easurable, <u>A</u>ttainable, <u>R</u>esult-focused, and <u>T</u>ime-focused (5). Each learning objective must be specific such that its achievement can be measured through formal or informal assessment. The objective must be attainable given the prior knowledge and abilities of the students, as well as the available time and resources. The learning objectives are result-focused in that the content designer must consider what results one is looking for and how one will know the learning objectives have been achieved. Last the learning objectives must be time-focused in that the objectives build on each other and, as a group, must fit within the available time for the course.

Assessment of the flipped classroom has often been based on qualitative student-perception surveys (6). In our case, assessment of the flipped classroom in comparison to the prior approach comprises formative assessment including for instance considering how well students understand and problem-solve for topics known to be troublesome. Summative assessment is done by testing the students in exams and quizzes using a bank of multiple choice problem solving questions. Performance of the students can be compared for cohorts taught with the prior approach and the current cohort. Since the most able students are likely to perform at a similar level with the two approaches, the comparison is focused on the bottom third of the students who may be more engaged and compelled to apply the course content in multiple situations with feedback from their classmates and the instructor. Table 1below shows examples of learning objectives and corresponding assessment items for the lesson on diode rectifiers and linear dc power supplies.



Learning Objective	Assessment
1. Describe the block diagram of a linear dc power supply and explain in their own words the function of each block	1. Students draw the block diagram of a linear power supply. They sketch and explain the shape and amplitude of the voltage waveform after each block.
2. Analyze the 3 main voltage rectifier circuits. Describe in their own words the circuit operation. Compute the rectified output voltages (peak – mean – reverse)	2.a. Students verbalize their thought process for analyzing a diode rectifier circuit. 2.b. Students recognize the type of rectifier used in a circuit and determine which equations they should use to quantify the output voltage. 2.c. Students compute the voltage output and load current for the 3 types of diode rectifiers, which include both positive and negative rectifiers.

Table 1: Example of paired learning objectives/assessment items identified prior to the design of the learning content.

Process assessment includes checking attendance to determine if the students are more inclined to attend class than in the past. In addition, a rubric completed by an observer and scored on a 1-4 Likert scale is used to rate acquired skills, group interaction, and teamwork. Items in the rubric include:

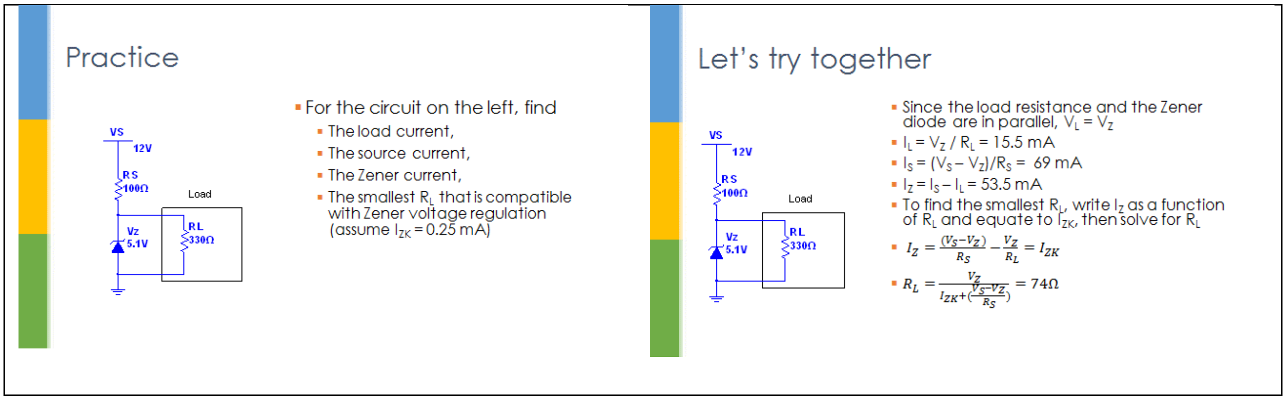
- Apply fundamental laws of circuit analysis to simplify a circuit and solve for the requested parameters
- Recognize fundamental circuit blocks in a circuit
- Apply analysis methods for the circuits blocks above to derive output voltage or current
- Interpret the output of a Multisim-simulated circuit using understanding of components and circuit blocks
- Identify and locate a fault in a circuit based on observed output vs. predicted output
- Select fundamental circuit blocks and realistic components to design a circuit block that satisfies specified design requirements
- Apply knowledge and strategies learned in class to analyze a circuit that is different from those studied in class
- Implemented a circuit or system to meet specified design requirements
- Considered alternatives to solving the design problem
- Use judgment to recognize improbable values and erroneous computations in the analysis of a circuit
- Clear explanation of process, solution, or reasoning that appears convincing to the class

- Planning and division of labor. Efficient and accurate planning and solution formation

Implementation of on-line learning content:

The learning content comprises video lessons developed with PowerPoint to present the course material in a series of 15 lessons, each corresponding to approximately one week of course content. The content is interspersed with sample exercises which require application of previously presented content to analyze a typical circuit. Some exercises include presentation of a detailed solution while others are not solved in the presentation and left for the students to solve on their own.

After a video lesson is developed, a script of the narration is prepared to provide the text to be included in the audio part of the lesson. The screencasting software Camtasia is then used to include a narration and animations in the form of callouts to the PowerPoint lessons. A quality USB microphone, such as model AT2020 from Audio-Technica is used for the sound recording. To narrate the lessons using the text script while navigating through the slide presentation, it is convenient to use a computer system with two video monitors. After the audio narration is completed, it is edited within Camtasia to remove verbal “hedges” and add the callouts. In particular, callouts are used to prompt the students to stop the presentations and solve the sample problems before reading through the solution. An MP4 video file of each lesson is generated within Camtasia for posting on the Blackboard website associated with the Medical Electronics course. An example of activity exercise and related solution included in the video lesson on Zener diodes is shown in Figure 1. . The duration of the video lessons vary between 15 and 30 minutes, with the intent of assigning no more than 15 min of viewing at a time.



Practice

- For the circuit on the left, find
  - The load current,
  - The source current,
  - The Zener current,
  - The smallest R_L that is compatible with Zener voltage regulation (assume $I_{ZK} = 0.25$ mA)

Let’s try together

- Since the load resistance and the Zener diode are in parallel, $V_L = V_Z$
- $I_L = V_Z / R_L = 15.5$ mA
- $I_S = (V_S - V_Z)/R_S = 69$ mA
- $I_Z = I_S - I_L = 53.5$ mA
- To find the smallest R_L, write I_Z as a function of R_L and equate to I_{ZK}, then solve for R_L
- $I_Z = \frac{(V_S - V_Z)}{R_S} - \frac{V_Z}{R_L} = I_{ZK}$
- $R_L = \frac{V_Z}{I_{ZK} + (\frac{V_S - V_Z}{R_S})} = 74\Omega$

Figure 1: Example of exercise slides included in a video presentation

Applying the flipped classroom paradigm to the Medical Electronics course:

The video lessons and in-class activities developed using the flipped classroom are tested during the 2014 Spring semester during the entire semester and with the instructor who previously taught the course with the traditional format. The first 15 min of class time are spent with the students discussing in small groups their lesson summary, answering each other’s questions, and comparing solutions to the sample problems from the lessons. Students then work collaboratively to solve circuit analysis problems, including computer simulation exercises developed with

National Instruments “Multisim” which test their understanding of circuit behavior when components change or become faulty. Open-ended design activities allow the students to design a circuit and test their design against pre-defined design requirements within the circuit simulation environment. During that time, the instructor circulates in the classroom to provide individualized and small group guidance. We expect that this first implementation will help us gain experience with the approach and improve the on-line content using the results of the assessment and feedback from the students. Note that the total amount of work required of the students for the course remains approximately the same as that required of them in the traditional format. Homework assignments are reduced by approximately 60% to make room for watching the video lessons and doing the practice exercises included in the lessons.

Application, analysis, and evaluation, are essential traits associated with engineering education that are promoted in the flipped classroom paradigm. By increasing the amount of time the students spend engaged in circuit analysis and design problems, and enriching the environment in which these activities are performed with peer learning and instructor feedback, the flipped classroom paradigm appears well suited for teaching and learning electronics in biomedical engineering curricula. Our experience will reveal some of the essential benefits of this pedagogical model for engineering education.

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