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Novel Practices in Teaching Circuit Analysis in an EET Program

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Abstract

Circuit analysis, recognized as the foundation of Electronic Engineering Technology (EET) curriculum, is critical to a successful educational experience for students in the EET program. In this paper, we present a number of effective teaching practices adopted in both lectures and laboratory sessions for an introductory circuit analysis course in an EET curriculum. In lectures, besides the traditional instructor-present teaching style, our practices are featured by using videos to aid lecturing and inviting upper-level students presenting their projects in class. Moreover, this course also serves as an additional advising opportunity by offering a program overview presentation by the EET coordinator. In laboratory instructions, we created a series of instructional videos to help students get familiar with essential lab equipments and useful lab procedures. In addition, we recruited undergraduate teaching assistants to assist lab supervision. Students' feedback and classroom assignments and test results confirm that these adopted teaching techniques are effective and help to meet the specific challenges that are present in our EET program. In addition, grades of students' assignments from a higher level circuit analysis class are provided to further demonstrate the effectiveness of some of the teaching techniques.

I. Introduction

Offered as the first major course in Electronic Engineering Technology (EET) curriculums, circuit analysis aims to build students a solid coursework base and prepares them for subsequent more advanced courses. Moreover, at Western Washington university (WWU), the circuit analysis course also serves as a "first light" to expose students to the field of electronics and the EET major and to attract undeclared students to major in this program.

Due to students' background (with limited math skills such as pre-calculus and little electronic circuit knowledge) and the nature of the course material, circuit analysis often is viewed as one of the most challenging and difficult lower-division EE/EET courses. As such, keeping students engaged in the course material are critical [1], [2]. Consequently, how to effectively teach this course to achieve desired course outcomes often poses challenges to instructors.

In addition, within the past few years, the EET program at WWU has witnessed a pleasing trend - a growing enrollment, which brings another challenge. Prior to 2005, the normal class enrollment was about 25 students. Recently, the enrollment has jumped to over 40 students per class. Without imposing excessive personnel resources, how to effectively handle a larger class due to an increased enrollment is an emergent task. To alleviate these challenges, besides the traditional teaching approaches, we have explored and implemented a number of new teaching techniques in this course in our EET curriculum since 2011 and have gained positive and promising teaching outcomes and students' feedback. In this paper, we present and share some of our successful practices and effort with colleagues in this area.

The teaching elements we introduced are targeted to address a number of challenges as follows.

- Keeping students engaged and inspiring students' interests in the field of electronic circuits and majoring in the EET program.
- Introducing students the "big picture"of the EET program and curriculum.
- Efficient and effective laboratory instructions to cope with an increasing enrollment and a larger class size.

Our effective practices are adopted in both lectures and laboratory instruction. In lectures, the implemented teaching strategies are featured by using multimedia components such as videos, in-person upper-division students' project demonstrations, attending senior design demo event, and a guest talk by our EET program coordinator to present a program overview.

On the other hand, well-structured and delivered lab components are always paramount in a hands-on oriented EET program. Efficient and effective lab instruction to cope with the enrollment increase is an urgent need. To address this issue, we have proposed and implemented a few successful solutions including recruiting upper-division student teaching assistants (TAs) and developing multimedia instruction tools such as tutorial videos to introduce students with essential lab instruments. The roles of the TAs, the scope of tutorial videos, and the benefits of these practices will be presented in Sections III and IV. We would like to note that some of these techniques may have been used in some EET and other STEM programs in other institutions. Adopting them in our program is an initial step to modernize this course and also has been targeted for different challenges such as the aforementioned increasing enrollment, in addition to serving the common goals (e.g., engaging students).

The paper is organized as follows. In the next section, we describe the teaching techniques adopted in lectures. Section III provides detailed discussion on the teaching practices for laboratory instructions. Assessment results from this course and a higher-level sequence course that demonstrate the effectiveness of the implemented teaching techniques are provided in Section IV. We conclude in Section V.

II. Teaching Practices in Lectures

In this section, we discuss several teaching practices we have experimented since spring 2011 in circuit analysis lectures. This course aims to achieve a number of desired course outcomes as summarized in Table I. Our objectives are multi-fold: firstly introduce students to the fundamental topics of circuit analysis and achieve the desired course outcomes; secondly, use this course as an opportunity to engage and inspire students in the field of electronics and circuits. Thirdly, we believe this course is a natural venue for group advising given that it is the EET entrance course and the first major course. Students taking this class mostly are either pre-majors or majors in EET. A significant portion of student population do not have circuit analysis background and are only equipped with pre-calculus math before taking this class. Consequently, the class material and coverage are tailored to meet students' need and background. Specifically, this course is Algebra based and we do not expect students to use higher-level math skills. Moreover, as the first course in a two-course circuit analysis sequence, this course aims to provide a broader introduction to circuit analysis and is not meant to involve in-depth calculus-based analysis. The topics and the extent of coverage are listed in Table II.

To achieve the desired course outcomes and the aforementioned goals, we adopted various teaching techniques besides the conventional instructor-present approach. For instance, a number of carefully selected short videos that tied with the lecture content were shown during lectures. Two types of videos were selected: some were tutorial videos to explain basic concepts or topics, e.g., a tutorial video on inductors; others were introductory videos of latest hi-tech developments and advances in EE/EET with a focus on circuits and systems. A list of videos used in spring 2011 and 2012 is provided in Table III. Another effective practice is to invite upper-class students such as juniors and seniors to showcase their course projects or/and part-time fun projects in class. These project are closely related to the course material presented in lectures and helped students to connect what they learned in classroom to real-life applications. This practice has been highly regarded by students as evidenced in their class surveys. In addition, a 30-minute overview of the EET program was offered by our program coordinator, which gave students an overall understanding and a big picture of the program and the curriculum. Lastly, in the end of the quarter, students were encouraged to attend the annual EET senior design demonstration event to witness the hard-work and engaging projects seniors had accomplished. Interactions with the upper-class students greatly benefit the freshman students as reflected by students' comments in their teaching evaluations of this course. Students' feedback from both the teaching evaluations and the end of quarter class surveys have been very positive and encouraging, which indicate that these teaching

TABLE I

DESIRED COURSE OUTCOMES

1	Understand and be able to apply standard electrical units and engineering notation.
2	Understand and be able to apply basic electrical concepts including voltage, current, resistance, power and energy.
3	Be able to apply ohms law in resistor circuits with voltage or current sources.
4	Be able to analyze series-parallel resistor circuits using KVL, KCL, Thevenin equivalence, Norton equivalence, and/or superposition.
5	Understand the basic concepts involved with capacitance and inductance.
6	Be able to analyze RC or RL circuits at initial and steady-state conditions.
7	Understand and express AC signals.
8	Have an introductory level of understanding and competency in analyzing simple AC circuits using complex numbers, reactance, impedance, and phasors.
9	Be able to measure and manipulate voltages, currents, and resistance in the lab using a DMM, VOM, DC Power Supply.
10	Be able to measure amplitude, frequency, and phase of an AC signal using the oscilloscope and function generator.
11	Know the standard color code including tolerances and be able to read values off of numerically labeled resistors, inductors, and capacitors.
12	Be able to construct circuits using real parts and a solderless breadboard and be introduced to basic tools such as wire cutters, strippers, and pliers.
13	Know the basic safety and usage rules for the lab and behave in a professional and responsible manner. Know and follow the requirements to not destroy or overstress equipment and parts.
14	Understand the need for completing work in a timely manner.

practices are effective and beneficial. Detailed assessment results based on students' survey results are provided in Section IV.

III. TEACHING PRACTICES IN LABORATORY SESSIONS

In the Laboratory portion of this course, we have adopted two effective teaching practices to aid laboratory instructions. Lab activities have played an essential role in the engineering education [3] and are especially crucial to an introductory circuit analysis course. Well-designed and effectively conducted lab activities not only reinforce students' understanding of course material but also familiarize students with essential lab instruments and build up their hands-on ability to prepare them for subsequent circuit courses.

As mentioned in the preceding sections, lately, our EET program faces additional challenges due to a rapid growth in circuit analysis course enrollment. In spring 2011 and spring 2012 quarters, the

TABLE II

TOPICS COVERED IN LECTURES

Topics	Extent of coverage
Introduction	SI units, prefixes and engineering notation, circuit diagrams
Voltage, current, resistance	
Ohm's law, power, and energy	
Basic dc analysis - series and parallel circuits	familiar with KVL, KCL, etc
Basic dc analysis - methods of analysis: source conversion, mesh analysis, nodal analysis	
Basic dc analysis -network theorems: superposition, $Thévenin's$ and Norton's theorem	
Capacitance and inductance	covers transient and steady-state
AC fundamentals	AC waveforms, phasors, average, RMS values, etc
R,L,C elements and impedance concept	complex numbers, RLC with sinusoidal excitation reactance and impedance calculations

TABLE III

VIDEOS SHOWED DURING LECTURE INSTRUCTIONS

Order of Video	Topic
1	Six-sense Device
2	Cool unmanned ariel vehicle dancing
3	Robotic ARM
4	A day of glass
5	Inductor tutorial video

class enrollments were over 40 per quarter. This increase of class size demands two lab sessions for each lab assignment given that our lab capacity is 24 students per session at maximum. To alleviate the personnel resource tension due to the resulting larger class size and newly added lab sessions, we have implemented various teaching strategies. Firstly, since 2011, we have recruited upper-level EET undergraduate students (mostly seniors) as lab TAs to aid lab instruction under the supervision of the faculty member who taught the lecture and the lab sessions, i.e., for each lab session, the faculty member worked with a TA to supervise the lab activities. The TAs were selected from a pool of junior and senior EET students who have a strong electronic circuit background and hands-on experience.

Moreover, to efficiently deliver the lab instructions and help students get familiar with fundamental lab instruments such as power supply, DMM, oscilloscope, and function generators, we created and introduced a series of short lab instructional videos with the help of TAs. The topic of each video is listed in Table IV. Video learning has been regarded as a powerful and expressive non-textual way to capture and present information through a multi-sensory learning environment [4], [5]. Many studies reported that video learning tools may improve learners ability to retain information and enhance learning outcomes due to vivid and fascinating presentations, e.g., [5], [6], [7]. In addition, we benefit from using instructional videos in the light of facilitating a large class size in laboratory instructions. In our videos, a TA demonstrates and explains step-by-step how to use those lab instruments. In the beginning of a lab session, students first watch a tutorial video as instructed, then proceed to conduct the required lab activities. We notice that this two-step lab procedure allows the instructor to effectively manage and supervise a relative large class of up to 24 students in each lab session.

As discussed in the next section, the students feedback indicates that these teaching practices are beneficial and successful. In addition, faculty feedback and grades of these students from a higher level circuit analysis course also suggest these practices are effective.

TABLE IV
INSTRUCTIONAL VIDEOS CREATED AND USED FOR LABORATORY INSTRUCTIONS

Order of Video	Topic	Web link
1	Tri-power supply	http://youtu.be/LNGvV5lH3Os
2	DMM basics	http://youtu.be/RMbb0-9jHsk
3	DMM follow up on AC RMS measurements	http://youtu.be/Pk2MaUd72TA
4	Oscilloscope and function generator	http://youtu.be/jppxhizFCvA

IV. Feedback and Assessment Results

To gauge the effectiveness of the adopted teaching practices, anonymous student surveys were conducted by the end of spring quarter 2012 while students were taking this class. A number of questions were asked regarding students' opinions on both lecture-related and laboratory-related teaching techniques. These survey results are presented in Table V, Table VI, and Table VIII, respectively, based on the feedback from 33 students who answered the survey questions. As indicated from Table V, all 33 students unanimously agree that the program overview presentation, the junior/senior students' project demos, and the short videos in lectures are helpful and suggest continue offering these in future circuit analysis classes. It is not surprising that students think highly of both the program overview presentation and the junior/senior student project demos. Students not only got informed about the general picture of the EET program and also were inspired by witnessing what upper-level students could achieve in their projects. In addition, some constructive comments were provided by students. For example, one suggested that the program overview presentation may be moved to an earlier time in this course. Another student noted that to conserve lecture time, the presentation could be offered at different occasions rather than during the lectures. These input will be incorporated into our next offering of this course.

Similar to the lecture portion, consistent survey results were obtained regarding the use of tutorial videos and student TAs for laboratory instructions. Interestingly, as shown in Table VI, it seems that the power supply tutorial video is not as most helpful as the other two tutorial videos with a 49% rating in the category of "very helpful", while majority of students think the oscilloscope and function generator video is the most helpful one with a rating of 76% in the same category. This suggests that video learning and video instruction tools are more effective for more complex learning topics and lab equipment. For simple topics the traditional manual or instructional document may be sufficient and effective. As reflected from student's comments, some suggested to add tutorial videos on breadboard and circuit wiring. Others demand more in-depth tutorials on oscilloscopes. In our future offerings, we will consider these suggestions into our video design and creation.

Besides student surveys, we also present some classroom assignments and exam grades to demonstrate the effects of the lab tutorial videos. In Fig. 1 we illustrate the grade distribution of exam questions on power supply and DMM, and of a lab assignment on using Agilent x3000 series oscilloscope for AC signal analysis. The exam grades show the percentage of students who answered the exam questions correctly and the lab assignment grade shows the percentage of students earning a grade in the $90\% - 100\%$ range. We note that many factors may contribute to students' performance. To rigorously evaluate the effectiveness of tutorial videos, more carefully designed assessment measures need to be developed.

As observed from Table VIII, all students but one agree that the student TAs are helpful and are valuable complement to the instructor. As suggested by a student, the future selection of TA candidates may emphasize both the ability of fulfilling the TA responsibilities and good personalities to interact with lower-level students.

Valuable lessons have been learned through the past two offerings of this course in spring 2011 and spring 2012. For instance, the time constraint may be an issue given our 10-week quarter system. It makes class time management a challenge when we need to incorporate videos into designated course content. We also found that, as expected, the majority of students are in favor of using such multimedia tools (e.g., tutorial videos in our case) and think these are more effective in facilitating students getting familiar and mastering of the lab instruments. Interestingly, a few students indicated that they would prefer the traditional manual or instructional document approach.

In addition, the effectiveness of the teaching practices especially the lab instruction practices adopted has been further validated by the feedback from the faculty member who taught the same group of students for a higher level circuit analysis course in fall 2012. This course is the second course in the two-course circuit analysis sequence and is built upon the first circuit analysis course. The faculty member noted a number of observations regarding students' performance:

1) The students were well prepared for this higher level circuit analysis course as shown by the grades of their first exam;
2) The students were quickly adapted to the lab equipment and familiar with oscilloscope, function generator, DMM, and other basic lab instruments as indicated by their first a few lab exercise performance.

Some of the grades of these students in the higher level circuit analysis course are provided in Table VII.

In summary, the faculty feedback and grades of the same students from a higher level circuit analysis course also suggest these practices are effective in achieving desired course outcomes and prepare students well for more advanced course works.

V. Conclusions

In this paper, we summarize several effective practices in teaching an introductory circuit analysis course in the context of an undergraduate EET curriculum. In lectures, to engage students in the EET program and inspire them in studying circuits, we experimented various techniques such as inviting upper-level EET students to showcase their projects and offering a program overview presentation by our EET coordinator. Moreover, to cope with the large class size due to increasing enrollment, we recruit student teaching assistants to aid laboratory supervision and introduce a series of instructional videos in lab instructions. Student feedback and class assignments and test results indicate that these adopted teaching techniques are effective and successful. We will incorporate the constructive suggestions from students' feedback to further improve the effectiveness in future offerings of this course.

TABLE V

STUDENT SURVEY QUESTIONS AND RESULTS - LECTURE PORTION

Question	Yes	No	Additional Comments
The program overview presentation by our EET Coordinator is helpful	33 (100%)	0 (0%)	- This may be offered earlier in this course. - Given our class time constraint, this may be offered outside of lectures.
Do you suggest keep the program overview presentation in future offerings of this course?	33 (100%)	0 (0%)	
The junior/senior class project demos are helpful	33 (100%)	0 (0%)	- Please have more of such demos in class. - Very cool and interesting. - Inspiring, helped us to grasp what we will do in the future (courses). - They inspired me to do my own projects. - Helped students get excited about the future.
Do you suggest keep these demos in future offerings of this course?	33 (100%)	0 (0%)	
The short videos played during lectures are helpful	33 (100%)	0 (0%)	- More links to online videos for extra learning. - More videos such as TED videos. - Video lectures?

TABLE VI

STUDENT SURVEY QUESTIONS AND RESULTS - LABORATORY PORTION ON INSTRUCTIONAL VIDEOS

Question	Very Helpful	Helpful	Not Helpful	Additional Comments
Tri-power supply tutorial video	16 (49%)	13 (39%)	4 12%	- Prefer detailed documentation to learn new equipment swiftly. - It is self-explained.
DMM tutorial video	21 (64%)	8 (24%)	4 12%	
Oscilloscope and function generator video	25 (76%)	4 (12%)	4 12%	- Cover all aspects of an oscilloscope. - Visual learning is good.

REFERENCES

[1] B. Oakley II, "A virtual classroom approach to teaching circuit analysis," *IEEE Transactions on Education*, vol. 39, pp. 287–296, August 1996.

[2] A. Sterian, B. Adamczyk, and M.M. A. Rahmanand, "A Project-Based Approach to Teaching Introductory Circuit Analysis," in *Proc. the 38th ASEE/IEEE Frontiers in Education Conference*, Saratoga Springs, NY, October 2008.

[3] L.D. Feisel and A.J. Rosa, "The role of the laboratory in undergraduate engineering education," *Journal of Engineering Education*, pp. 121–130, Jan 2005.

[4] A. Hampapur and R. Jain, *Video Data Management Systems: Metadata and Architecture*, McGraw-Hill, New York, NY, 1998.

TABLE VII

STUDENT SURVEY QUESTIONS AND RESULTS - LABORATORY PORTION ON STUDENT TAS

Question	Yes No	Additional Comments
The student TAs are helpful	32 1 (96%) (4%)	- Very helpful. Knowing that they had made similar mistakes in labs is kind of a relief. - They are good complement to the instructor. - I 'd suggest check their personalities.
Do you suggest keep student TAs in future offerings of this course?	33 0 (100%) (0%)	

TABLE VIII

STUDENT GRADES FROM A HIGHER LEVEL CIRCUIT COURSE IN FALL 2012

Assignment	Topic	Average	% of students achieving 80% or above
Lab 1	AC analysis using scope and function generator	14.8 (Full mark 15)	100%
Test 1	AC analysis, AC network theorems	73.97 (Full mark 85)	82%

[5] D. Zhang, L. Zhou, R.O. Briggs, and J.F. Nunamaker, *Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness*, Elsevier, 2006.

[6] G.C. Nugent, "Pictures, audio, and print: symbolic representation and effect on learning," *Education Communication and Technology Journal*, vol. 30, pp. 163174, 1982.

[7] M.R. Syed, "Diminishing the distance in distance education," *IEEE Multimedia*, vol. 8, pp. 18–21, 2001.

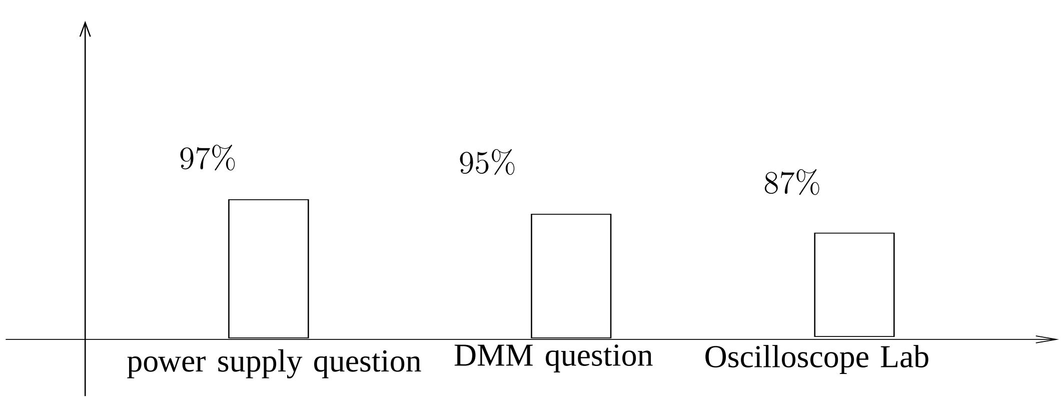

Fig. 1. Exam and lab assignment results.