Development of a Circuit Analysis Course with Open Educational Resources and Assessment

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Abstract

Our university has supported and incentivized faculty to adopt high-quality open educational resources (OER) instead of expensive textbooks for their courses. Our circuit analysis course was re-developed with new adoption of OER available online. The course was first offered in summer 2018 and offered again in summer 2019. The students accessed the free OER contents through a revised course website in the learning management system Canvas in those two years. Feedbacks were obtained from the students on the adopted OER. Assessments were conducted on the learning outcomes through examinations and end of term student surveys. The preliminary findings were that the OER, like the textbook adopted previously, were helpful to the students in learning the new concepts and in preparing them for the exams. The student rating for the instructor did not change in a significant way with the adoption of OER.

Keywords

Open educational resources, pedagogy, engineering education, assessment

Motivation

This is a paper analyzing the impact of our first attempt in the adoption of OER in our electrical engineering curriculum. The motivation of using OER is described in the following. It was reported by the U.S. Bureau of Labor Statistics[1] that from January 2006 to July 2016, the Consumer Price Index for college tuition and fees increased 63 percent, compared with an increase of 21 percent for all items. Over that period, consumer prices for college textbooks increased 88 percent and housing at school (excluding board) increased 51 percent.

Similar studies with focus on textbook affordability and acquisition were conducted within our state. All the state's public higher education institutions participated in the studies. Their published report [2] stated that the cost of textbooks continued to negatively impact student access to required materials and learning, student success, and the completion of their study.

Effort has been made at our local university to support and incentivize faculty to adopt high-quality OER instead of expensive textbooks. The main objectives of the effort was to reduce the cost of attendance by adopting free or very low cost instructional materials. OER are teaching and learning materials in the public domain or released under a license for free access.

In our electrical engineering curriculum, the first course that we attempted with OER was circuit analysis EEL3111. It is a junior level core course that covers basic analysis of electrical circuits. Topics include DC circuit analysis methods, circuit theorems, operational amplifiers, transient analysis of first- and second-order circuits, and phasor methods for sinusoidal steady-state

analysis. The course was re-designed for using OER to support the course instead of the textbook. The re-design is described in the next section.

Course re-design

The circuit analysis course was restructured into eight modules. The learning objectives of these modules are summarized below.

- Module 1: Understand the basic electrical quantities. Identify basic circuit elements. Understand the associated circuit properties.

- Module 2: Calculate voltage and currents using voltage and current divider formulas. Calculate voltage and currents by applying Kirchhoff's law. Apply nodal and mesh analysis techniques to solving electric circuit problems.

- Module 3: Apply circuit theorems to solve circuit analysis problems. The circuit theorems include Millman's theorem, superposition principle, Thevenin's and Norton's theorems, source transformation theorem, maximum power transfer theorem and the transformation between Y and Delta circuits.

- Module 4: Formulate the properties of capacitors and inductors. Compute equivalent capacitance and inductance connected in series and parallel. Understand the behavior of capacitors and inductors under DC condition.

- Module 5: Analyze operational amplifier circuits using nodal analysis and the ideal op amp model. Understand the applications of inverting, non-inverting, summing, and difference amplifiers

- Module 6: Review of complex numbers. Transform sinusoids to phasors. Transform time-domain circuits to frequency domain circuits. Apply DC circuit analysis techniques to analyze AC circuits.

- Module 7: Find the transient responses of source-free first-order circuits. Obtain the step responses of first-order circuits driven by DC sources.

- Module 8: Determine the initial conditions of second-order circuits. Obtain the transient responses of source-free series and parallel RLC circuits. Obtain the step responses of series and parallel RLC circuits driven by DC sources.

The topics for each of the modules above were identified. Online search for OER was carefully conducted. Library staff was consulted for finding these materials. The selected OER supported the learning objectives and matched the topics. The links for these materials were sorted out and specified in the modules. A course website was developed in the learning management software Canvas to accommodate these modules and links. An example of the modules is shown in Fig. 1. The module began with its learning objectives and followed by the topics to be covered, the links to the OER covering those topics, the assignments, and solutions. During the face-to-face lectures, the concepts in the OER were explained and elucidated with examples. Additional

examples not in the OER were also covered in the lectures helping students to gain deeper understanding of the topics and to develop problem solving skills.

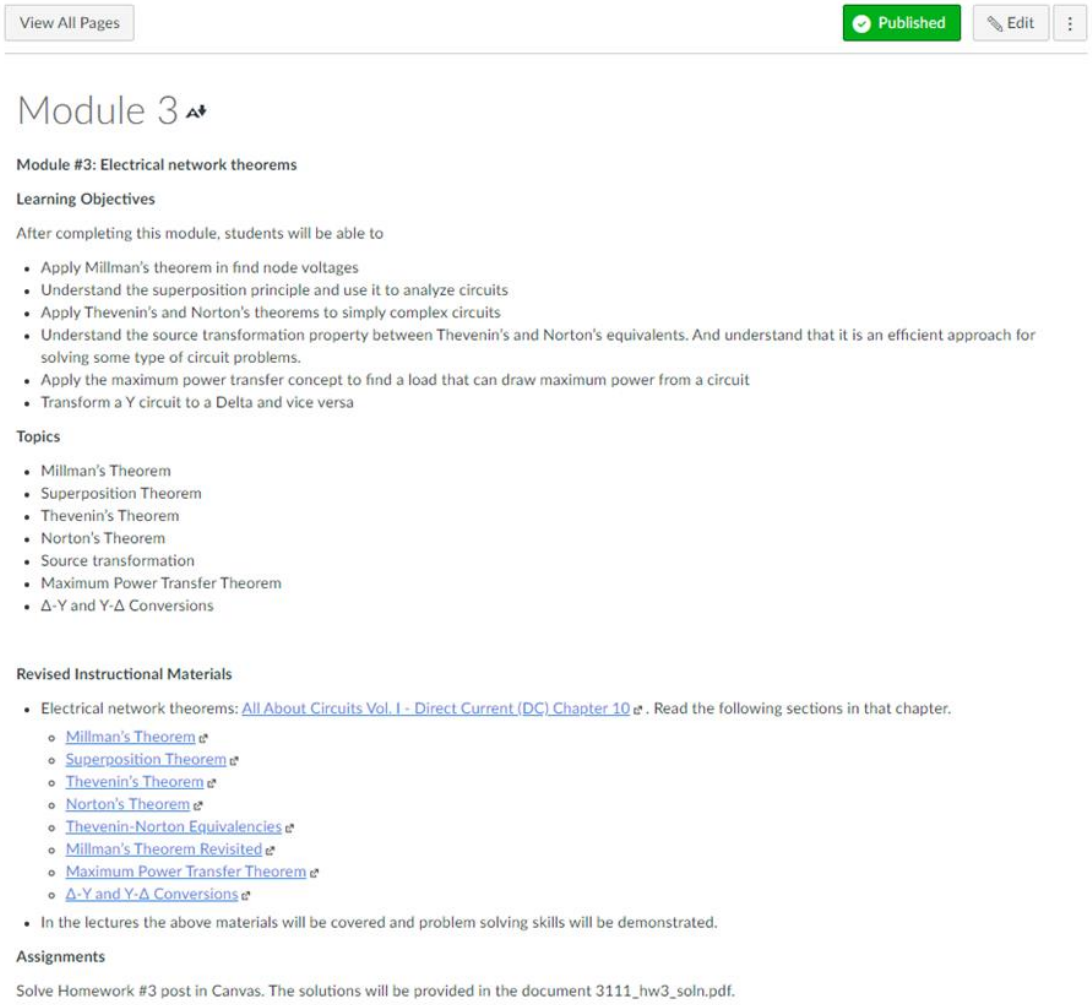

Fig. 1: The structure of the modules.

In the search for OER to support the learning objectives and topics of the modules, it was realized that there were many open materials such as text, videos, interactive online materials that appeared matching at first glance. Further reading and viewing of these materials revealed that the majority of them were not matching the level of the course. It took a substantial period to sort out and to select what were the applicable OER for the course. The selected OER materials came with few examples and no homework problems and solutions. Additional time was spent on looking for good examples, matching homework problems, working out the solutions by hand, documenting the solutions, and posting them in the course website on Canvas. For those students interested in reading more examples, the low cost supplemental book[3] was recommended. Copies of the book were made available in the library for the students to check out.

Assessments

The circuit analysis course incorporated with the OER was offered to the students in the summer terms of 2018 and 2019. Assessments were conducted. The assessment consisted of written comments from students and exam scores. For the written comments, students were requested to enter their comments voluntarily in the discussion board of Canvas and to give a rating of the OER educational materials on the scale of 1 (lowest) to 10 (highest). The following comments were received in the summer term of 2018.

- I enjoyed using the online instructional material for this course and would score it an overall 7/10. All About Circuits was written very well and made it easy to understand complex topics, but what I liked most about it was having access to it on my phone, allowing me to have it whenever I needed it. Schaum's Outline's Electric Circuits was great for homework problems, I just wish there were more examples/problems per topic.

- 7 [the rating indicated is 7 out of 10]

- I liked the online materials. They provided information about the concepts in an understandable way and they were free! I would rate them an 8/10.

- The online materials that were provided were above adequate for our needs for this class. Since it was used as a precursor to the material and problems were provided and solved by the professor our ability to learn the material was met. Textbooks are far too expensive to be worth the hundreds of dollars that we are charged and I hope that some of my other classes take this approach to save us students some money further down the line. I would rate the quality of online materials as an 8 overall.

The student comments indicated that they had no objection to using OER in the course. Some students liked the OER because it was free, easily accessible, and adequate for the course. Some students preferred to see more examples in the OER. More examples were covered in the classroom to meet this need. Their rating of the OER materials was average. It was neither very high nor very low. The mean score was 7.5 out of 10. Since the materials were not specifically written for our course, such numerical rating was expected.

For the exam scores, four years of data are shown in Table 1 below. In the table, Exam 1 covered the materials in Modules 1 and 2. Exam 2 covered the materials in Modules 3, 4, and 5. Exam 3 covered the materials in Modules 6, 7, and 8. The level of the exams in those four years were about the same. In the years 2016 and 2017, the textbook[4] was used in the course. In the years 2018 and 2019, no textbook was used and OER was adopted for the course.

The averages of the scores of Exam 1 through 3 in 2018 and 2019 were insignificantly higher than those in 2016 and 2017. This indicates that the adoption of OER did not change the performance of the students in the examinations in any significant way.

To investigate whether the adoption of OER would affect the instructor’s rating in the university administered student evaluations, four years of such ratings are shown in Table 2. The average of the ratings in 2018 and 2019 were insignificantly higher than that in 2016 and 2017. Again, the

data indicated that the adoption of OER did not change the instructor's rating in any significant way.

Table1: comparison of exam scores

Circuit analysis course	Exam 1 (out of 100)	Exam 2 (out of 100)	Exam 3 (out of 100)	Average	Standard deviation
Summer 2016 (used a textbook[4])	67.6	72.8	63.8	68.1	4.5
Summer 2017 (used a textbook[4])	74.6	77.0	74.0	75.2	1.6
Summer 2018 (used OER)	74.9	77.0	70.6	74.2	3.3
Summer 2019 (used OER)	78.5	81.1	72.5	77.4	4.4

Table 2: instructor's overall rating

Circuit analysis course	Overall rating of instructor (out of 5)
Summer 2016 (used a textbook[4])	4.63
Summer 2017 (used a textbook[4])	4.09
Summer 2018 (used OER)	4.29
Summer 2019 (used OER)	4.59

Concluding Remarks

It has been the culture in academia that traditional textbooks are essential. Thinking outside the box, an attempt was made to use OER instead of a textbook for our circuit analysis course. The preliminary findings were that such approach did not change significantly the students' exam scores nor the instructor's rating. The students were open to using OER because it was free, easily accessible, and the contents were sufficient for the course. Further studies will be conducted to confirm whether this form of pedagogy will change student's interest in and the engagement with the course. The total enrollment for the two summer offerings in 2018 and 2019 were 87. The cost of the textbook used before the adoption of the OER materials was approximately $200. This effort of adopting OER materials saved the students a total of about $17,400 in those two years. The course adopted with the OER was submitted to Affordability Counts[5] for evaluation. Affordability Counts is a statewide initiative that recognizes faculty throughout the state who adopt low-cost materials. The course was recognized and awarded the Affordability Counts medallion.

References

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