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Positive Effects of a Small Grant for Creation of Open Education Resources

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Positive Effects of a Small Grant for Creation of Open Educational Resources

Abstract

Open educational resources have been shown to have the potential to improve student learning outcomes while lowering student costs associated with curricular materials. University of the Pacific competitively awarded small grants of $2500 to encourage faculty to create or adopt Open Educational Resources (OER) to help reduce student costs or enhance the student learning experience. This paper outlines how the grant award was used to create open tutorial resources and lab materials that helped students independently learn to use the simulation software Simulink in conjunction with a Digital Signal Processing course. Students were required to review the OER materials and complete the lab experiments on their own, outside of class time. Having these tutorial resources available online freed up class time that previously had been used to demonstrate use of the software and to assist students as they completed lab exercises in class. The class time saved has been used for active in-class problem solving and for review sessions prior to examinations. The additional time available to work with students actively in class has had the salutary effect of improving student performance in the course: the class GPA has shown increasing trends (effect size = 0.42) after incorporation of the OER materials. Other positive effects of the OER grant are: (1) Student competence with Simulink is just as good when students learn and use the tool independently without consuming class time. (2) Student satisfaction with respect to the availability and effectiveness of the OER materials as measured by a survey is high.

Introduction

Open Educational Resources (OER) are "teaching, learning and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions."[1] OER that range from short documents to peer-reviewed textbooks in a variety of subject areas are available at no cost from sites such as OpenStax (www.cnx.org) and Merlot (www.merlot.org). Recent articles[2,3] have reported on efforts at universities to lower costs for engineering students by replacing traditional textbooks by OER. Faculty at institutions that have adopted OER have conducted studies on their impact on student outcomes; a recent paper[4] that aggregated results from 36 different studies concluded that "students achieve the same or better learning outcomes when using OER while saving significant amounts of money."

In 2018, University of the Pacific issued a call for proposals for creation or adoption of open educational resources that could save students money by avoiding textbook costs, or that could help support teaching / improve student learning. The author applied for and was awarded a $2500 grant to create open tutorial resources and lab materials to enable students to independently learn to use the simulation software Simulink in conjunction with a Digital Signal Processing (DSP) course. DSP is a mathematically intensive course, and computer simulation allows students to quickly compute and visually observe results of signal processing operations.

Simulation gives students another pathway besides a mathematical approach to engage with the course material and can help visual learners better grasp the material. The DSP course uses traditional programming in Matlab and block-diagram-based simulation via Simulink to explore signal processing concepts. Prior to the OER grant, the instructor performed in-class demonstrations to help students learn to use Simulink. This approach consumed instructional time and had the drawback that students tended to forget usage details between experiments, requiring further expenditures of class time. Further, students worked on the in-class Simulink labs in teams of two, a method which could not guarantee that each student actively gained experience with Simulink. The OER grant resulted in the creation of four openly accessible Simulink-based laboratory experiments with detailed instructions[5] and an accompanying video introduction to Simulink. These lab experiments were deployed in the Fall 2018 semester and required each individual student to view the video tutorial, complete the lab experiments on his or her own – outside of class time, and submit a lab report. This individual student engagement with Simulink has helped to increase student competence with the software. Student response to the Simulink tutorials and OER labs has been positive: all respondents to a student survey agreed that the Simulink tutorials and labs were effective in helping them learn to use Simulink. Students also agreed that the online availability of these Simulink tutorial resources was useful, allowing them to refer to the resources instead of asking the professor if they forgot simulation procedures.

The use of OER to shift student learning of Simulink and some of the Simulink lab work outside the classroom has resulted in savings of instructional time. These time savings been used to introduce cooperative problem-solving activities in class, and to provide interactive review sessions before exams. These changes have led to improved student performance in the course: available data shows that the mean student grade point after introduction of the OER labs has increased (effect size = 0.42). The improvement in student performance can be linked to pedagogical approaches such as active learning that can have a "powerful impact upon students' learning."[6] Active learning has been defined[6] as "anything that involves students in doing things and thinking about the things they are doing." The OER Simulink labs have promoted active learning in two ways: first, each individual student is actively engaged in working through the labs, in contrast to the previous team-based approach. Second, the in-class cooperative problem-solving activities that the OER labs enabled introduce breaks in class and allow students to process information they have just been exposed to as they work on problems alongside their neighbors. Active learning promoted by the OER labs is also linked to the flipped classroom[7] approach: students learn to use Simulink on their own outside of class using video tutorials and online resources, and are able to engage more actively with the material in class due to the instructional time savings. The in-class problem solving exercises also foster informal cooperative learning cooperative learning between students[8]. Cooperation between students has been found to enhance academic achievement and serve as an avenue to help enhance interpersonal skills[9].

The OER labs and their impact on the DSP course

The OER materials developed to introduce students to Simulink include four lab experiments with detailed instructions, and a video tutorial guiding students through the first of these labs. These resources are openly accessible[5] via Creative Commons licensing to anyone who wishes to use them. Students can access these materials and submit lab reports using the learning management system Canvas. Table 1 enumerates the OER labs that have been developed and outlines their content. The in-class labs in the DSP course are mostly Matlab-based and require programming. Some of the in-class lab experiments require use of Simulink: this design allows students to leverage their out of class Simulink experience and further expand their skills. Table 2 lists the in-class Simulink exercises and shows how they are linked to the OER labs.

Lab Experiment	Content
Lab 1: Introduction to Simulink	Uses Simulink to create sinusoidal signals, sample them at a desired sampling rate, and view the original sinusoid and its samples. Includes a video depicting the entire simulation procedure
Lab 2: Exploration of Aliasing	Sample a 1kHz sinusoid and a 11kHz sinusoid at a sampling rate of 10K samples/sec and show that aliasing occurs (samples of both sinusoids are identical)
Lab 3: Impulse Response and Step Response of Systems	Use Simulink to explore the impulse response and step response of low-pass and high-pass filters.
Lab 4: Spectra of Signals	Use Simulink to view the power spectrum of a signal with sinusoidal components. Calculate theoretical signal power and compare with Simulink results.

Table 1: Content of OER labs that students perform outside class

Link to OER lab	Simulink exercise performed during in-class session
After OER lab 3	Pass music through digital filters. Classify the filters as low-pass or high-pass based on audible characteristics of the output signal.
After OER lab 3	Use frequency response concepts to predict and verify gain and phase shift of a sinusoidal signal that is passed through a linear system.
After OER lab 4	Implement a 3-band audio equalizer with adjustable band gains in Simulink. Perform live adjustment of band gains as music is passed through the equalizer.

Table 2: List of in-class Simulink exercises

Figures 1and 2 help illustrate the synergy between the OER labs and the in-class lab. Figure 1 shows a block diagram from OER lab 3 that uses Simulink to view the impulse response and step response of a discrete-time system on an oscilloscope. The subsequent in-class lab has students explore whether a filter is a low-pass or high-pass filter by analyzing its step response (students have not been exposed to frequency response concepts at this point in the class). Students also use Simulink in class to pass a music signal through the filters and identify the filter type by listening to the resulting audio output. Figure 2 depicts the corresponding block diagram: the switches in the circuit allow the user to listen to the original music clip, the low-pass filtered version of the music clip, or the high-pass filtered version of the music clip. The fact that students have already worked on the response of a discrete-time system in the OER lab allows the in-class Simulink exercise to go smoothly without much intervention from the instructor.

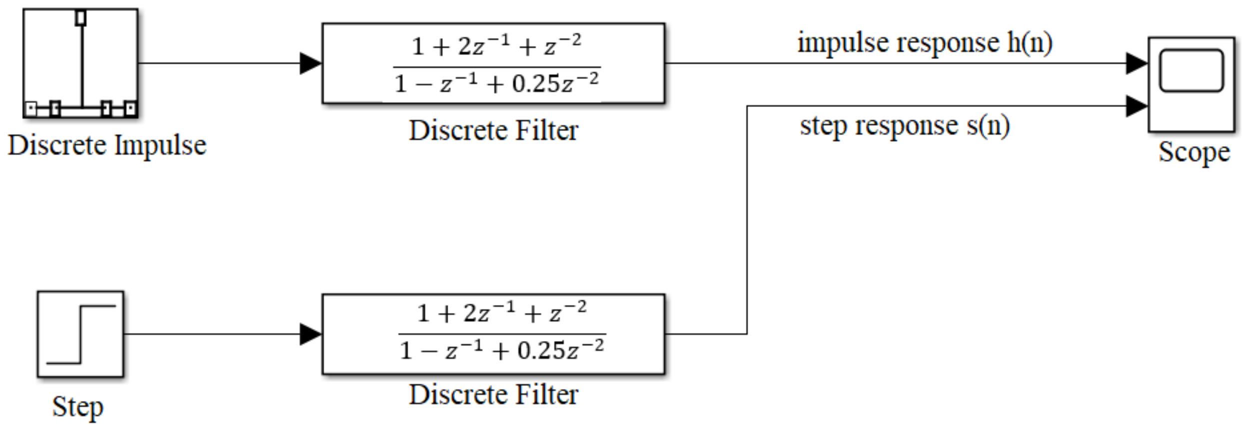

Figure 1: OER lab exploring impulse response and step response of systems

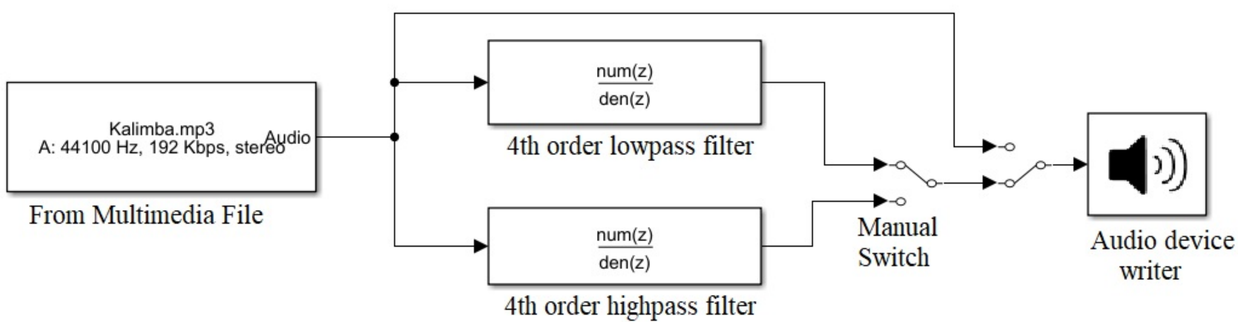

Figure 2: In-class Simulink exercise exploring music passed through different types of filters

Assessing the effects of the OER grant effort

<u>Overall student performance as measured using course grades</u>

The OER grant was awarded in the Summer of 2018; development of the OER resources was completed in the summer, and the resources were deployed in the Fall 2018 offering of the Digital Signal Processing course. During the Fall 2018 and 2019 offerings of the course it appeared to the instructor that students were performing better on Simulink exercises and on the exams in the course; the OER materials and the active learning opportunities that they facilitated appeared to be causing this positive effect. The author decided to conduct a study to see if there was a measurable improvement in student performance. The available data consisted of three semesters of student course grade data prior to Fall 2018 (pre-OER data, 35 students total) and two semesters of student course grade data for Fall 18 and beyond (post-OER data, 38 students total). Assessing student learning and development is best accomplished by using instruments to assess specific student knowledge or skills. This method of assessment could not be performed as the pre-OER group had already completed the course. The only avenue available to compare student performance was using course grades. Final grades in the course were based on only three factors: homework, examinations, and lab work. All three factors reflect student competence with the course material, and the course grade thus provides a measure of overall student performance in the course.

The decision to use course grades as a measure of student performance was followed by a decision to exclude failing (F) grades while making pre and post OER comparisons of student performance. F grades are commonly received by students facing personal problems; they appear semi randomly in some terms, and inclusion of these grades can skew class GPA when the number of students is small. Figure 3 shows the grade distributions of the 35 pre-OER and 38 post-OER students: the x axis lists each letter grade and the corresponding grade point. The figure shows that the post-OER group earned a higher percentage of A, A- and B grades, while the pre-OER group received a higher percentage of B-, C+, C, C- and D grades.

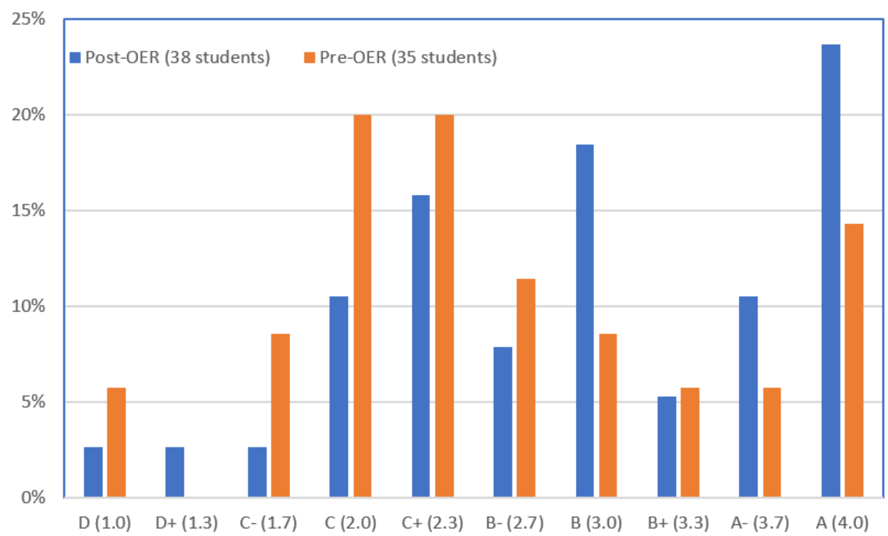

Figure 3: Grade distribution percentages for pre-OER and post-OER groups

Before beginning statistical comparisons, a few observations regarding the composition of the pre-OER and post-OER student groups needs to be made. First, all the students in the study were taught by the same instructor using the same instructional methods (except for the OER initiated changes in the post-OER group) and the same grading methods. Final course grades were assigned based on guaranteed grade thresholds (total score > 90% guarantees an A grade, total score > 80% guarantees a B grade, etc.) and natural breaks in student scores; no curving was performed. Apart from the OER interventions, the learning environment, exam format, and method of assigning grades was thus the same for both populations. Second, DSP is a core course that is taken by all students in the program. The students in the pre-OER and post-OER groups thus represent the set of all students in the program at a given point in their progress towards graduation. There is no cherry picking of students: the quality of the pre-OER and post-OER groups reflect the quality of students admitted to the program.

Statistics for the pre and post OER data of Fig. 3 were computed using grade points in place of letter grades and are summarized in Table 3. The mean of the post-OER group is clearly higher than that of the pre-OER group, showing that the OER interventions have had a positive effect.

Group	Population Size	Mean	Standard Deviation	Pooled Standard Deviation
Pre-OER	35	2.60	0.85	0.86
Post-OER	38	2.96	0.85	

Table 3: Statistics for pre-OER and post-OER data

Effect size[9,10] has often been used to quantify the effect of an intervention. The effect size (ES) is calculated as follows:

$$\text{ES} = \frac{\text{Mean of group after intervention} - \text{Mean of group prior to intervention}}{\text{Pooled standard deviation}}$$

The effect size is $\text{ES} = (2.96 - 2.6)/.86 \approx 0.42$: the intervention has thus improved the student mean by 0.42 standard deviations. Hattie[10], who has used effect size to quantify the impact of interventions on student learning found that the average effect size across all interventions he studied to be 0.4; he considers any intervention that produces ES > 0.4 to be above average. Using this metric, the interventions resulting from introduction of the OER labs in the DSP course have had an above average effect on improved student learning.

Student competence with Simulink

The DSP course does not have a separate lab time slot; class time naturally flows between lecture and lab at appropriate junctures in the course. The weight of the lab exercises is 15% and the purpose of the labs is to reinforce theory via simulation. Prior to introduction of the OER labs, student learning of Simulink was facilitated by instructor led demonstrations followed by in-class student work on the Simulink lab components. Students worked in teams while completing the lab exercises, and students having difficulty with labs received assistance. Students therefore generally received good lab scores except in cases of negligence or absence. Prior to introduction of the OER labs, students could ride on the coattails of their lab partners; it was possible for one of the lab partners to be doing the lion's share of the work.

The OER labs require each individual student to perform the labs and submit lab reports, an improvement over the previous team-based approach. Students have easily worked through the labs using the video and tutorial resources and have rarely approached the instructor for assistance. Student scores on the individually performed Simulink labs were excellent: the lowest median class score on the set of 4 Simulink labs over the Fall 18 and Fall 19 semesters was 95%. As outlined earlier, the in-class labs include some additional Simulink-based tasks. The instructor has observed that students were easily able to tackle these tasks based on their prior individual experience with Simulink. Based on individual student scores on the OER labs and subsequent ability of students to complete the in-class Simulink labs with little assistance, it is clear to the instructor that student competence with Simulink has improved since introduction of the OER labs.

Student feedback on the value and efficacy of the OER materials

A survey was conducted at the end of the Fall 2018 semester to get feedback from students on the value and efficacy of the Simulink OER materials. This was not a scientifically designed survey but rather a quick survey to get feedback from students on how they felt about the usefulness of the OER materials, and their effectiveness in helping them learn how to use Simulink. The three survey questions and the student responses (from 13 survey respondents) to these questions are summarized in Table 4. The table shows that all respondents agreed that the Simulink tutorials were useful and effective and that they valued the experience working with Simulink in the DSP course. Students also valued the availability of the Simulink tutorials online. For all three survey questions more students selected Strongly Agree than selected Agree: a plurality of students thus strongly agreed that the OER materials developed were useful and effective.

Survey Question	**Number of Student Responses**			
	Strongly Agree	Agree	Strongly Disagree	Disagree
It is useful to have the Simulink tutorials available for reference	8 (62%)	5 (38%)	0	0
The Simulink tutorials and labs were effective in helping me learn how to use Simulink.	7 (54%)	6 (46%)	0	0
I value the experience that I have gained from using Simulink in the DSP class	8 (62%)	5 (38%)	0	0

Table 4: Student survey questions and responses

Impact on the author

Working on using OER to help improve the DSP course has had a significant impact on the author. The first impact was awakening him to the fact that many universities have been working to increase the number of courses that use OER to help lower cost barriers to education. The Scholarly Publishing and Academic Resources Coalition (SPARC) publishes a directory of OER activities[11] at North American campuses that allows one to evaluate the level to which OER has penetrated a campus, including details such as whether course catalogs designate courses as OER courses. The OER efforts reported in this paper have also resulted in positive student comments in end of semester course evaluations. The author plans to continue to expand use of OER, including replacing textbooks by OER in other courses that he teaches.

Conclusions

Receiving a small OER grant helped the author create online resources to help students learn to use Simulink simulation software, and complete Simulink labs outside of class. Moving Simulink lab work outside of class hours has resulted in savings of class time; this time savings has allowed the instructor to introduce active problem solving in class and interactive review sessions prior to exams. The increased active engagement of students has resulted in improved student performance, as measured using student grades. The interventions made possible by introduction of OER resources have resulted in improved student grades (effect size = 0.42). The author is very pleased that natural changes to the classroom environment that resulted from a small OER grant have had a positive impact on student learning.

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