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Improving a Flipped Electromechanical Energy Conversion Course

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Improving a Flipped Electromechanical Energy Conversion Course

Our University's Electrical and Computer Engineering Department has offered an elective course in Electric Machinery for decades. With increasing focus on renewable energy and power electronics in the curriculum, we felt the need to modernize this course so that it provides a better learning experience and appeals to more students. Over a period of two terms, we updated the hardware lab equipment, designed new hardware lab experiments, added new computer modeling experiments, and added power electronics content. This produced excellent student evaluations and good learning outcomes in fall 2013. In fall 2014 we "flipped" the course, with mixed results. Instructor-student interaction did increase, but there was no significant improvement in exam or lab outcomes, and the student evaluations decreased significantly from the non-flipped version in fall 2013. Some students preferred the flipped format, but they were outnumbered by those who did not. We seemed to fix something that wasn't broken.

This paper will focus on continuing course format changes to improve both outcomes and student evaluations. Only the successful flipped classroom elements were retained for fall 2015. In the spring 2015 term, 134 video screencast example problems were added to the instructor's teaching of Linear Circuits & Systems 2. The addition of optional video content yielded significant improvements in both outcomes and evaluations, compared to the instructor's previous teaching of Linear Circuits & Systems 1. This suggested use of video content to supplement, but not replace, in-person teaching of new material, as in a blended classroom.

Therefore, in the fall 2015 term, Electric Machinery was offered with supplemental video content. The course schedule also changed. The class now meets for two 75-minute lecture periods and one two-hour lab period per week, versus the one-evening-per-week class session in the past. The instructor also incorporated two items from the ASEE National Effective Teaching Institute (NETI-1) summer 2015 offering. The first new element is detailed learning objectives, which are presented as study guides, amounting to six full pages of objectives for the course. The second new element is a "scaffolded" handout for each class, encouraging students to actively complete content and take notes. In addition, the instructor has added animations using the ANSYS Maxwell software that serve as demonstrations for students during the software labs. Students also complete short online quizzes before class to promote preparation. Thus, our fall 2015 class has assumed a blended classroom format, in which face-to-face and technology-enhanced instruction are used together.

We evaluated this classroom for the degree of active learning, problem solving, student collaboration, and instructor-to-student interaction using a structured behavioral observation protocol known as the Teaching Dimensions Observation Protocol (TDOP). We compare our observational results between fall 2014 and fall 2015 to formally assess differences in classroom practices. Impacts on student final exam performance and student evaluations are also discussed.

The History of this Course in our Electric Power Concentration

Our department offers four concentration areas to EE majors, and approximately one third of them choose the Electric Power concentration. (The other concentration areas include Digital Systems, Electronics and Devices, and Communications and Signal Processing. Computer Engineering is a separate major offered within our department.) In order to complete the Electric Power concentration, students must take Power System Analysis 1 and three electives, chosen from a list that includes this electric machinery course. It is our only course offering a lab experience in electric power, and it carries 4 credits instead of our normal 3 credits.

We don't have an undergraduate power electronics course, but a few of our seniors take a Master's-level power electronic course. In department exit surveys of graduating seniors, this lack of a junior-senior level power electronics course has been pointed out consistently. We now have an undergraduate power electronics course to be offered annually, beginning in the spring term of 2017. In the meantime, this course has covered some undergraduate power electronics material to partially fill the gap.

This course has been offered every fall term for many years. Prior to 2013, the course covered a sequence of traditional topics: magnetic circuits, three-phase transformers, DC machines, induction machines, and synchronous machines. The class met for 140 minutes one evening per week. Seven lab assignments were scheduled for completion at different times in the week. The machines lab had facilities for only one student team to work at a time. Beginning in 2013, the course was updated as follows[1]:

- 2013 – Changed the textbook to include more power electronics content[2], began to use a partially completed new hardware lab for one assignment, and incorporated six computer lab assignments.
- 2014 – Expanded to five hardware lab assignments and seven computer lab assignments, with two optional field trips. The textbook was the same and only minor changes were made to the syllabus. The main change was to flip the course, but with mixed results[1].

In 2013 and 2014, students complained about the long evening class periods, and the pace of material covered in only one meeting per week. The flipped classroom did not address these issues. For 2015, the instructor was able to reschedule the course into three meetings per week, and adopted a blended classroom approach.

Literature Review: The Flipped EE Classroom

The flipped classroom, which was implemented in this course in the fall 2014 semester, is an active-learning approach that enables higher-engagement activities during class, such as problem solving, with the instructor present as a guide; this is done by having students review lecture content beforehand using media such as online videos[3, 4].

Upon a review of the literature, we found other electrical engineering courses that have been flipped, with mostly positive results. In a signal processing course, the instructor noted that it took a few weeks for the students to adapt to the new environment, engage with their peers, or ask for assistance[5]. However, by the end of the term, less than 10% indicated a preference for traditional lecture. In addition, the instructor noted a very clear improvement in achievement with the flipped classroom, with an overwhelming majority performing at a high level on the final exam - as never seen before. In a required junior-level electromagnetics course, the instructor noted that students asked many more questions in the flipped format, including higher-thought-level questions[6]. Although exam scores showed no significant difference with the flipped format, the instructor felt that students achieved a higher level of learning, better understanding, and better problem solving skills. In addition, student evaluations of the course were higher with the flipped approach. The flipped classroom has also been used in an electronic systems engineering program to enhance retention of lecture information[7]. To this end, in a student survey in the power systems course, 62% indicated that the flipped approach was more useful than traditional lecture for presentation of material, and 80% felt that in-class assignments were a better use of class time.

However, another instructor noted a high level of frustration in his flipped sophomore electrical engineering course near the end of the term when students struggled to understand some concepts[8]. He expressed caution about using the flipped method for all subjects and indicated that for complex topics, it may be necessary to have micro-lectures. Similar to this experience, students' perspectives towards the flipped classroom in an electrical engineering principles course became less favorable near the end of the term, when the material became harder[9]. In the middle of the semester, 67% of survey respondents indicated they wanted to continue with the flipped format; however, by the end of the semester, just 57% would have preferred the flipped format for the course again.

Literature Review: The Blended EE Classroom

In the fall 2015 semester, the course was conducted in a blended fashion. Blended learning aims to integrate face-to-face teaching with online learning[10, 11, 12]. With blended learning, aspects of face-to-face instruction are replaced or enhanced by online or technology-based experiences, such as simulations, remote labs, content videos, and assessments/quizzes[10].

A blended approach has been taken with other electrical engineering courses, with benefits noted by both students and instructors. For example, this approach was taken in an undergraduate power electronics course, and survey respondents noted that the on-line quizzes were beneficial to their understanding[13]. Remote laboratories sometimes comprise blended learning environments. In the area of control theory, a remote lab was used so that students could remotely experiment and integrate the practical with the theoretical aspects of the course[14]. A similar goal was noted in another controls engineering course, in which a web-based simulator was used to complement the theoretical-based lectures[15]. In this controls course, there was an increase from 63% to 79% on an end-of-course exam, when compared to previous courses taught conventionally. A virtual lab in a physics course enabled students to build electrical circuits using components and tools within a graphical user interface, thereby simulating a real laboratory experience and driving active and independent learning, comprehension, and knowledge[16]. Finally, in a remote lab in a microcontrollers and robotics course, students cited the benefits of being able to repeat experiments anywhere or at any time (i.e., 81% agreed), as well as feeling more at ease than in a classical experimental setting (i.e., 66% agreed)[17].

Blended approaches have also been taken with entire electrical engineering programs. In fact, a German blended-learning Bachelor's program in electrical engineering was designed for non-traditional students who work[18]. The goal was to offer people employed in electrical engineering or technology positions the opportunity to receive a Bachelor's degree while still maintaining their jobs; therefore, the ability to complete online self-study was critical.

Literature Review: Detailed Learning Objectives

The preparation of detailed learning objectives for students, as was done in the fall 2015 semester, has been advocated by leading engineering educators[19]. Instructional objectives should ideally be explicit statements of tasks that students are expected to perform. For example, instructional objectives should contain action verbs such as *explain, estimate, describe, model, or critique* that may span Bloom's taxonomy[20, 21]. The greater the specificity of the task and the clearer the expectations, the more likely students will accomplish it and/or meet the expectations [21, 22]. These objectives can serve as study guides for exams, as was done in this course[22].

Format of the 2015 Course

The course was scheduled for 75-minute lecture periods on Monday and Wednesday, with a 110-minute lab period on Friday afternoon. This change was important, as it allowed for better distribution of classroom activities and more time for student reflection and learning between periods. The instructor also adopted a different textbook[23] with more narrative, and the student evaluations reflected high satisfaction with this book. However, it was necessary to supplement with more updated material than with the previous book. The outline of major topics was similar to 2013 and 2014:

1. Review of the per-unit system and three-phase power (i.e. course pre-requisites)
2. Magnetic circuits and electromechanical energy conversion
3. Transformers, including three-phase connections and autotransformers
4. Torque production in rotating machines
5. Synchronous generators and motors (balanced three-phase)

6. Induction motors (balanced three-phase)
7. Power electronic converters and motor drives
8. Brief special topics: brushless DC motor, universal motor and (by request from a working, part-time student) DC machines

This is a conventional course outline, but with less emphasis on DC machines and more on power electronics.

The course marking scheme was:

- 5% on pre-quizzes for each lecture session, administered via our University's customized Blackboard-based Learning Management System (LMS)
- 30% on the best 10 out of 12 lab reports
- 40% on the best 5 out of 6 in-class quizzes, with formula sheet allowed
- 25% on a two-hour final exam, with formula sheet allowed

The lab assignments in 2015 were modified slightly from 2014:

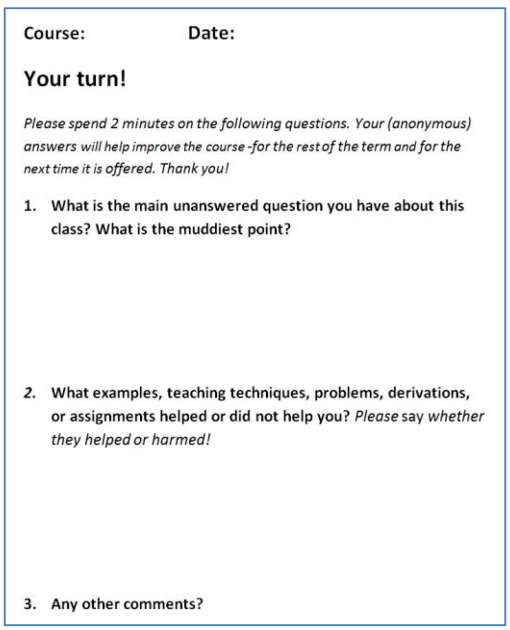
1. Hardware: lab safety and three-phase power
2. Computer: linear actuator model building and simulation
3. Computer: parametric and circuit analysis of linear actuator
4. Computer: transformer leakage and magnetizing flux paths
5. Hardware: three-phase transformer connections
6. Hardware: harmonics and motor starting inrush current
7. Hardware: switching transients and voltage sags
8. Computer: parameter optimization of a synchronous generator
9. Computer: parameter optimization of a brushless DC machine
10. Field Trip: tour of a local utility's high-voltage lab
11. Computer: parameter optimization of an induction motor
12. Hardware: induction motor control with variable frequency drive

A graduate teaching assistant (TA) was available to help supervise all of the lab sessions.

After the first week, the class voted to move lecture sessions into the electric power lab, i.e. the same room where hardware lab assignments were conducted. This room contains six clean and modern lab benches, where the students could spread out in groups of two to four, facilitating group work. This room also provided a modern environment, steeped in the atmosphere of electric power, compared to our assigned chalkboard-and-wooden-desk classroom. For most of the lecture sessions, the class worked through handouts, with segments of group work alternating with instructor questioning and lecturing. The instructor's notes were recorded by screen capture and posted to our LMS, using technology described earlier[1].

There were six in-class quizzes administered at bi-weekly intervals during lecture. During those lecture periods, the first 30 minutes was devoted to the quiz, and then after a short break, the class moved on to new material on handouts as described above. Students were able to prepare with detailed learning objectives, suggested practice problems from the textbook, and a student-prepared formula sheet. The total amount of testing time was comparable to nearly three regular exams, but with more frequent feedback on learning progress to both the student and the instructor.

Several times during the term, minute-surveys were delivered and collected from students, in the format of Figure 1. These were helpful in guiding review sessions before quizzes, and initiating new discussions.


Course: Date:

Your turn!

Please spend 2 minutes on the following questions. Your (anonymous) answers will help improve the course -for the rest of the term and for the next time it is offered. Thank you!

1. What is the main unanswered question you have about this class? What is the muddiest point?

2. What examples, teaching techniques, problems, derivations, or assignments helped or did not help you? *Please* say *whether they helped or harmed!*

3. Any other comments?

Figure 1: Minute survey adapted from[24]

The driving principle in 2015 was to break the class time up into shorter and more varied segments, focusing on "do this first" suggestions from the NETI-1 workshop. As described in more detail below, this produced better results than the flipped classroom in 2014.

Pre-Quizzes

Five per-cent of the grade was based on multiple-choice pre-quizzes administered through our LMS, designed to encourage students to read assigned textbook sections in advance of each lecture. There were 24 of these pre-quizzes in total; one of them due at the beginning of each lecture. There were only three questions per pre-quiz and re-takes were permitted. Figure 2 shows a sample question. The class average was 4.57/5.00 on all pre-quizzes, so these were "easy points".

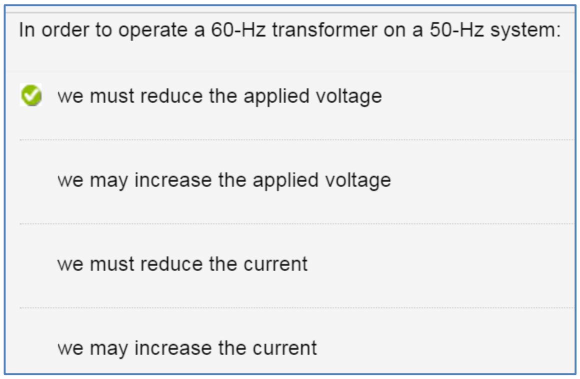


Figure 2: Sample pre-quiz question for textbook pre-reading

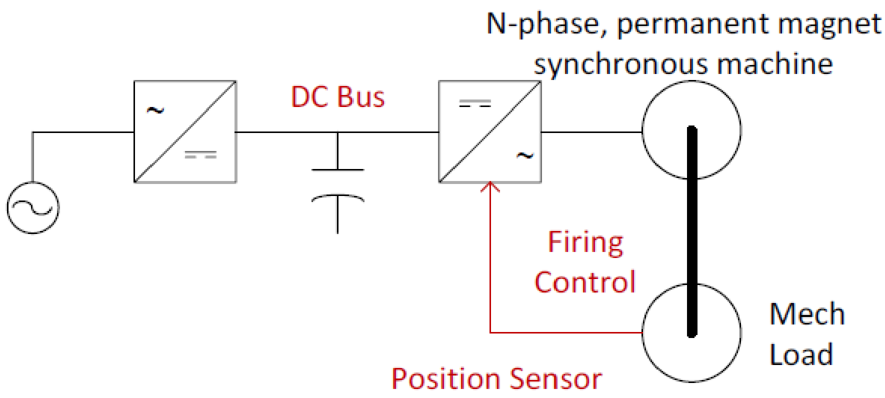
Handouts

Most of the lecture class time was organized around completing handouts, with time allowed for questions and discussion. Figure 3 and Figure 4 show a sample handout that was used to help organize a 75-minute class period. These handouts were provided as note-taking aids for the students, and not collected or evaluated. The instructor presented lecture material from notes, but in short segments of up to 15 minutes, writing on a tablet for display on the room's monitor. All drawings, like those in Figure 3 and Figure 4, were pre-loaded into the screen-casting software to save time and improve visual quality. In between lecture segments, the students worked on exercises in short group sessions, after which the instructor called on individuals to provide answers or suggestions. By interleaving activities this way, it was possible to keep most students engaged through the 75 minutes. This was one of two takeaways from the NETI-1 workshop.

Learning Objectives

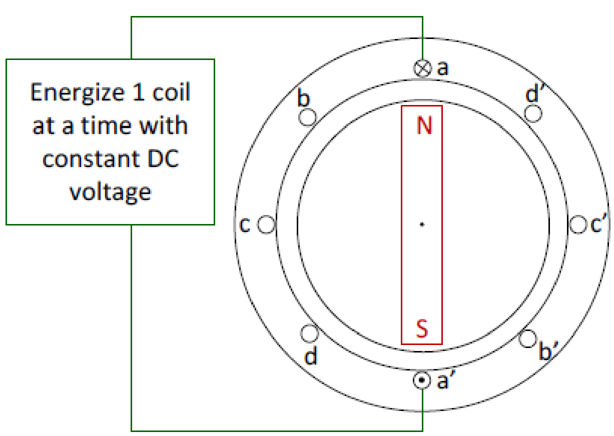
Figure 5 and Figure 6 show the learning objectives, presented as a "study guide" to students, for one of the six quizzes. This outline covered the material of five lecture periods, or two-and-a-half weeks of the course. The outline has much more detail than this instructor used in any other statements of course objectives. All questions posed on the quizzes and final exam were clearly tied to one of these learning objectives, and as the students realized that, they grew to rely on them for preparation. Practice problems were suggested, but not collected. Practice problem solutions were posted to the LMS. The quiz solutions were also posted and discussed in class.

This schematic shows a brushless DC motor with its power electronic drive. With a fiber optic mechanical position sensor, coupled to a variable-frequency output, this system can achieve precise control of speed and position on the mechanical load.



This cross section shows a 4-phase variant with one magnetic pole on the rotor. At this instant, voltage is applied to the a-a' coil, and currents flow in that coil.

1. For the instant shown, draw the rotor and stator magnetic field vectors, **Br** and **Bs**.
2. For the instant shown, label the rotor speed with **ω** in a clockwise or counter-clockwise direction.
3. On the axes provided, sketch in square wave phase voltage pulses that will achieve constant **ω**
4. How does this motor differ from the one examined in your last computer lab?



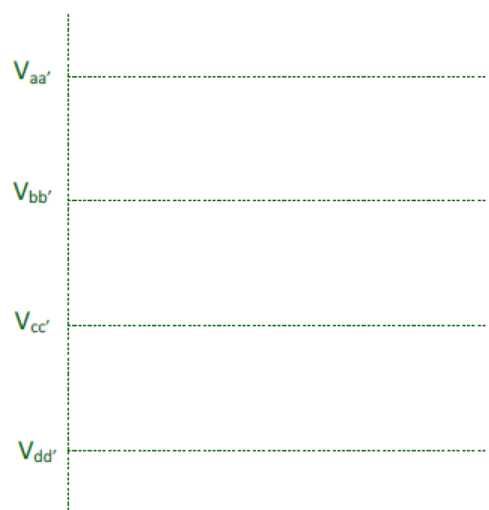


Figure 3: Front page of the third handout on synchronous generators

Fill in the following table of generator control options for different modes of operation. We have an entire course, ECE 1773, devoted to this subject.

Mode	**Standalone**	**Infinite Bus**	**Paralleled**
Start & synchronize			
Control power			
Control frequency			
Control voltage			

Consider the 133,689-kVA, 13.8-kV generator from the first part of Handout 10. We found Xs = 1.134 per-unit. The OCC test data went up to I_F = 1650 A and $E_A = 18200/\sqrt{3}$ V. In addition, assume that:

- δ_{max} = 60 degrees (steady-state stability limit)
- P_{max} = 127 MW (maximum prime mover output)
- P_{min} = 12.7 MW (minimum boiler heating requirement)
- Q_{min} = 50% of rating (end-turn heating limit)

On the axes provided below, draw the machine P and Q capability curves in % of 133,689 kVA.

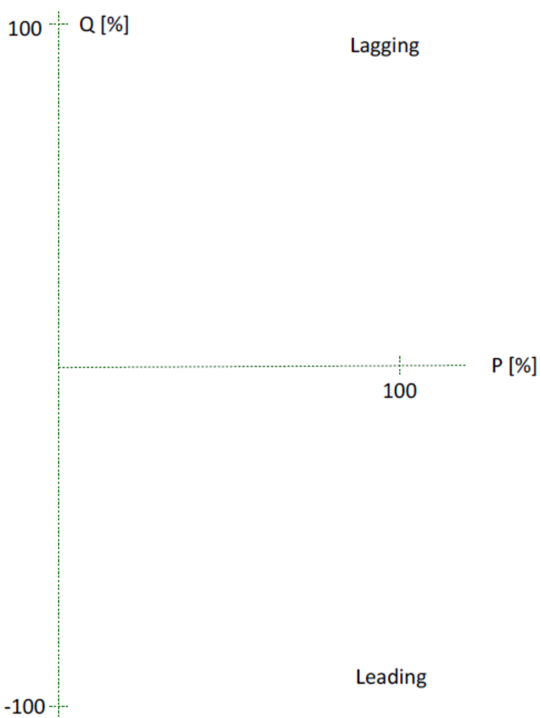


Figure 4: Back page of the third handout on synchronous generators

Learning Objectives (Study Guide) for Quiz 4

The fourth quiz will cover synchronous generators and motors, presented in chapters 4 and 5 of the textbook. The most important skills learned will involve constructing and calculating with the machine's phasor diagram, and obtaining the equivalent circuit parameters from test data. You should be able to:

1. Obtain the equivalent circuit parameters from open-circuit characteristic (OCC), short-circuit characteristic (SCC) and DC resistance test. Minimize the error from saturation while doing this.
2. Convert between per-unit and physical quantities for a synchronous machine, including voltage, current, speed, impedance, torque and power
3. Use the phasor diagram and/or the equivalent circuit to find:
   a. the machine excitation required for specified terminal conditions, or
   b. the terminal conditions with specified machine excitation
4. Transfer information from the phasor diagram to equivalent circuit, and vice versa.
5. From a phasor diagram or a solved equivalent circuit find the:
   a. electrical power
   b. machine torque
   c. efficiency
   d. power factor
   e. reactive power
   f. torque angle
   g. power factor angle
6. Explain in words what happens to the machine field current as power factor varies.
7. Sketch a machine's capability curve on PQ axes
   a. explain the reasons for stator current, field current, prime mover and under-excitation limits
   b. label those limits on the capability curve
8. Explain the differences between operating a synchronous generator standalone, and operating in parallel with one or more generators. Consider these aspects:
   a. Starting and synchronizing the generator
   b. Controlling real power
   c. Controlling frequency
   d. Controlling voltage
9. Explain in your own words the differences and similarities between synchronous generators and synchronous motors.
10. Describe three methods of starting a synchronous motor:
    a. reducing electrical frequency
    b. external prime mover
    c. amortisseur windings
11. Explain the pros and cons of using permanent magnets instead of field excitation in synchronous machines.
12. Explain how a permanent magnet changes the equivalent circuit and phasor diagram.

Figure 5: Page one of the learning objectives for synchronous machines

Suggested Practice Problems (Solutions manual is available on CourseWeb to check your work. Also, Chapman's data files and MatLab scripts have been posted to CourseWeb in a zip file; these include Figures P4-1, P4-2 and P5-4. You may use Chapman's MatLab scripts, or write your own MatLab scripts, or write your own MathCad sheets to help solve these practice problems. After solving a few problems by hand, you might learn more from writing and testing your own scripts than from repetitive manual calculations.)

- Questions 4-1 through 4-16
- Problems 4-2 through 4-5 (all about one generator)
- Problems 4-7 and 4-8 (per-unit)
- Problem 4-13 (saturation and per-unit)
- Problems 4-16 through 4-26 (all about another generator)
- Problems 4-27 (paralleling two generators)
- Questions 5-1 through 5-11
- Problem 5-1
- Problem 5-2
- Problem 5-6
- Problem 5-11
- Problem 5-12
- Problem 5-15

Figure 6: Page two of the learning objectives for synchronous machines

Video Segments in Fall 2015

Only a few of the video segments from fall 2014[1] were made available to students. For the most part, these were longer software demonstrations in preparation for the computer lab assignments. The videos presenting new material were tailored to a different textbook, so to some degree they were less appropriate for use in fall 2015. More importantly, the blended in-class presentation techniques proved more effective in fall 2015. The time to make new videos would be better spent in developing new in-class activities for future course offerings.

As in fall 2014, the web-based machine animations, originally developed by Riaz in MATLAB[25], proved very useful and popular for in-class demonstrations. The instructor developed new MATLAB and MATHCAD demonstrations to supplement them, and plans to continue with it.

Classroom Evaluation Methods

Behavioral observation of the non-lab portion of the course was conducted as a course evaluation measure in 2014 and 2015 using the TDOP – or Teaching Dimensions Observation Protocol[26]. Using the TDOP, the total class period was divided into a series of five-minute segments. For example, if a certain class period was 75 minutes in length, it had 15 observation segments, or time windows. During each segment or window, the various activities and practices within the protocol were recorded when observed. Thus, the percentage of segments in which a particular activity or behavior, such as student discussion, occurred could be determined. The usual method for comparing percentages or proportions when the samples (i.e., numerators) are large is the z-test of proportions, as described by Agresti[28]. However, when the samples are small, as in our case, a better and equivalent approach is Fisher's Exact Test, also discussed by Agresti[28]. In addition, since multiple TDOP categories were tested for differences, as shown in Table 1, Bonferroni's correction for multiple comparisons was applied[29, 30]. The Bonferroni correction reduces the alpha level applied to each individual test so that the family or overall error rate remains at $\alpha=0.05$. With this conservative correction, the alpha level for each individual-test *p*-value is set at $(0.05/m)$, where m is the number of tests conducted. An alternative way to view or apply Bonferroni's correction is to multiply each individual-test *p*-value by the number of tests conducted and use this new *p*-value as the observed significance level for the test. Finally, the inter-rater reliability associated with the assessment analyst's use of the TDOP was $\kappa=0.86$ (i.e., Cohen's kappa), based on her prior evaluation work with it. Values of κ above 0.75 suggest strong agreement beyond chance[27].

Analysis of Blended Classroom Activity

A description of the 2014 and 2015 classrooms based on the TDOP behavioral observation data is shown in Table 1, in which nine TDOP categories were tested for differences between the 2014 and 2015 semesters. Both semesters were characterized by a sizable amount of active learning and student engagement, as exemplified by the percentage of segments in which active student work (DW/SGW), problem solving (PS), student discussions during active work (ART), and student-generated questions (SCQ) occurred. The percentages of each set of TDOP categories were statistically equivalent when comparing the 2014 and 2015 classrooms, as shown by the rightmost column in Table 1. This suggests statistically equivalent amounts of active learning and student engagement during the flipped (2014) and blended (2015) semesters. Table 1 shows a higher percentage of lecturing in the 2015 classroom, as expected for a blended versus flipped classroom. However, the difference is not significant at $\alpha = 0.05$ upon correcting for multiple comparisons using Bonferroni's adjustment ($p_{new} = 0.01*9 = 0.09$). In addition, in the 2015 class, lecture was interspersed with accompanying worksheet exercises, in which students were asked to perform calculations or exhibit conceptual understanding during class, after completing pre-class assigned readings. This classroom format is reflected in the higher percentage of segments (in 2015) in which the instructor sought a factual answer or asked students to perform computations (DQ). Again, the difference is not significant upon applying Bonferroni's correction. Associated with the higher percentage of DQ in the 2015 classroom was a higher percentage of segments in which student responses (SR) to these questions or prompts occurred.

Table 1: Behavioral Observation Data

TDOP Category	Category Description	% of Segments Observed		Fisher's Exact Test *p*	
		Fall 2014	Fall 2015	No Corr.	Bonf. Corr.
DW, SGW	Active work by students (individual or group assignment or activity)	44.7	38.7	0.65	1.00
L, LPV, LHV, LDEM or LINT	Lecture of various formats	59.6	87.1	0.01	0.09
PS	Problem solving by students	44.7	35.5	0.49	1.00
ART	Verbal articulation of thoughts/ideas by students during active work	44.7	32.3	0.35	1.00
SCQ	Student comprehension/conceptual question	31.9	48.4	0.16	1.00
CQ	Instructor question to check for understanding	25.5	29.0	0.80	1.00
DQ	Instructor question seeking a factual answer, or a solution to a computational problem.	27.7	54.8	0.02	0.18
SR	Student response	29.8	45.2	0.23	1.00
MOV	Instructor movement & circulation among students	17.0	6.5	0.30	1.00

Learning Outcomes of the Blended Classroom

To directly assess learning with the various versions of the course (2013, 2014, and 2015), we compared their average final exam scores. Upon comparing the three cohorts, we found that their average pre-course GPAs were not statistically similar, with students in the 2015 semester having a significantly higher GPA than those in the 2014 semester based on a Kruskal-Wallis test (p=0.002), which we used given the small sample sizes. Therefore, an analysis of covariance (ANCOVA) approach was used to compare the final exam scores, with the pre-course GPA serving as a covariate or control variable. The final exam was similar across the three semesters, and the grader (i.e., the instructor) was the same during the three semesters.

The blended version of the course (2015) was associated with the highest final exam scores. The average raw (i.e., unadjusted) final exam scores were (in %) 87.0, 84.5, and 91.5 in 2013, 2014, and 2015, respectively. The adjusted final exam scores are shown in Table 2. These are the scores adjusted by the ANCOVA software using the pre-course GPA as the control. The blended version of the course also had the highest adjusted final exam score, as shown in the table. Since the sample sizes were small, we defaulted to the non-parametric version of the analysis of covariance, which is known as Quade's Test[31, 32]. Based on Quade's test, the difference in final exam scores was not quite significant, with a resultant p value of 0.096. However, the effect size, which measures the magnitude of the treatment effect or the practical significance, was large upon comparing the 2015 (blended) and 2014 (flipped) approaches, with Cohen's d=0.94[33,34]. The effect size between the 2015 (blended) and 2013 (non-flipped) approaches was medium, with d=0.53. The following threshold values were used to determine small, medium, and large effects as delineated by Cohen: d=0.20 (small), d=0.50 (medium), and d=0.80 (large)[35, 36]. This suggests the best final exam outcomes with the 2015 (blended) version of the course.

Table 2: Final Exam Scores – Comparison of Instructional Methods

Non-Flip (2013) NF	**Flip (2014) F**	**Blended (2015) B**	**Quade's Test**	**Cohen's *d* Effect Sizes**	**NF**	**F**	**B**
Adjusted Mean			**Overall *p***		**Sample Size**		
87.5	85.7	89.8	0.096	0.94 (B&F) 0.53 (B&NF) 0.41 (NF&F)	13	21	19

In line with the final exam outcomes for the flipped classroom in 2014, the instructor noted enhanced in-class student engagement in 2015 versus in 2014, with students in part asking more questions. The students' self-assessment of their learning, as indicated on the course evaluation survey, also somewhat coincided with these findings. In the flipped version of the course, the students rated their learning at 3.2 on a 1 to 5 scale (n=13), with 5 being most desirable. In the blended version in 2015, they rated it at 3.7 (n=10). In the non-flipped course, students rated their learning at 4.4 (n=9).

Further, based on the 2014 course evaluation survey, eight respondents did *not* prefer the flipped classroom (62%), three preferred it (23%), and two were undecided (15%). The instructor does not anticipate using the flipped method for this course in the future. He noted student dissatisfaction with the videos in comparison to live lectures. Interestingly, in a survey administered to the 2015 blended cohort, who used some of the videos that had been created for the flipped course, the students showed a preference for the use of a video as a software tutorial versus to learn new technical concepts or view sample problems. Specifically, on a 1-5 scale from strongly disagree to strongly agree, the software tutorial video was rated at approximately 3.7 in terms of its usefulness relative to in-class presentation of the same material. However, the conceptual and sample problems videos were rated at only approximately 2.7 each.

Conclusions

The instructor does not have tenure, so university teaching evaluations are very important. In fall 2014, when the course was flipped, these evaluations were significantly worse than in 2013. The key score is "teaching effectiveness", with an established target of 4 out of 5, and the results for this course have been:

- 2013 (traditional) – 4.43 out of 5.00
- 2014 (flipped) – 3.69 out of 5.00
- 2015 (blended) – 4.50 out of 5.00

This instructor would not repeat a flipped classroom experiment, even though it has clearly been successful for others. Instead, more in-class activities will be introduced in future course offerings, by adopting more suggestions from the NETI-1 workshop.

The course content will also evolve. Like most other electric machinery classes, this one has emphasized the tests for parameter determination, equivalent circuit analysis, phasor diagrams, etc. In other words, the principles and application of electric machines has been covered, but not the design of electric machines. The advent of our new power electronics elective will free up at least three weeks of time in this course to address machine design, and the instructor has funding from another source to develop course content in the area of electromechanical design. In fall 2016, the course will shift emphasis from application, still covered through lab work and computer automation of the equivalent circuit/phasor diagram analysis, to design, with an updated textbook[37] and expanded use of our finite element software for computer labs.

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