Blended Learning: Electrical Circuits for non-EE students

Abstract

With the advent of technology, the modern world is always changing around us. Our classrooms are becoming diverse with not just diversity of thought but also the diversity of culture, age, and learning styles and pace. Our academic institutes are creating welcoming environments for the students with learning disabilities in addition to the students with physical difficulties. As educators, its our responsibility to utilize the tools of our times to create more dynamic classes by promoting more engagement, better learning experiences and providing different avenues of learning to students with different learning styles. A blended or partially flipped classroom is the step in that direction. This methodology combines the advantages of in-class learning with out of class online learning. The out of class learning involves students preparing content on their own by watching videos and then taking online quizzes. A blended learning approach was adopted for the "Electrical Circuits" course at Missouri University of Science and Technology. This study presented here presents a comparison of different aspects of the blended learning format to that of a traditional lecture format for this course.

Introduction

The use of technology in education is not new but the use has been limited to enabling technology in traditional lecture format. Examples of this include using the combination of power point slides or similar tools with smart computer screens in class rather than the black or white boards, Learning Management Systems like Blackboard or Canvas for disseminating material and maintaining grades etc. This adoption of technology did not lead to any change in the pedagogical approaches. In more recent years, however, there has been a focus on finding creative ways to use the education technology to promote student engagement and to utilize class time for active learning engagements. [1,2]

One methodology in this direction is flipped or partially flipped (also known as blended learning) classrooms. The flipped classroom structure focuses on covering the conceptual and theoretical content of a course via video or online content whereas the classroom time is used for active learning based activities. The blended learning methodology is a combination of traditional elements and flipped format where some content is covered outside of the class time and some content is covered in the class. [1,2,3] For a blended course, more than 20% but less than 80% of the material should be covered electronically. [4,5] These formats offer a solution to the problem of limited classroom space and scheduling issues. In addition to this, following are some of the advantages for the students and instructors.

- Content delivery in limited amount of time
- Increased student motivation and engagement
- Better preparation by the students for a class
- Improved learning due to combination of self-paced nature of online/video content
- Increased availability of content for review or reference for homework, exams etc.

The term – flipped or blended may have been a recent addition to academia but the underlying principles are not entirely new; active learning along with experiential learning is based on the concept of "Cognitive conflict" that dates back to late 1960s and peer-assisted learning has its roots in "Proximal development" that was being studied in late 1970s. [1,2,6] Accessibility of technology has made it possible to bring these ideas into our classrooms. Use of online platforms has made it possible to track student engagement and progress; merely dissemination of information outside of class is not enough, reception of it by the students is more important.

Self-paced learning is the key element of blended format and is most advantageous to the students. Self-paced learning allows students to control the learning schedule that suit their needs and learning goals.[7,8] This control also allows students to revisit the material as many times as they need aiding learning for those students who might be averse to asking questions of their instructors about the same topic again and again. The feedback collected in the study presented shows that students really liked the ability of choosing their own pace and being prepared for the class ahead of time. Due to multiple advantages of using blended and flipped-classroom structures, multiple studies have been conducted in wide variety of engineering courses like entry-level courses, advanced courses, service courses for non-electrical engineering students etc. [9,10,11,12]

A blended learning approach was adopted for the Electrical Circuits course at Missouri University of Science and Technology. Electrical Circuits is the fundamental course in electrical engineering for non-Electrical Engineering students. The nature of this course presented unique challenges and it was thought that a blended learning approach might help overcome those challenges. This study compared the blended learning format to a traditional lecture format. The levers used for comparison were: 1) amount of content covered, 2) student performance on exams, and 3) student satisfaction in terms of perceived learning in new format. Details of the process, changes in the structure of the class, and motivations behind driving this change are presented. Student feedback on the changed format was collected by way of a survey. The survey responses along with a comparison of the student exam performances are also presented. Based on the student feedback and established research findings [13], some changes to the content adapted for blended format are already under way. The instructor feels that the flexibility in developing video content is a good opportunity to fix the content and seeks to continue adding new content or make changes to reflect accumulated experience and student feedback.

The course under consideration

The Electrical Circuits is an undergraduate level course at Missouri S&T intended for non-EE students. The content primarily includes AC circuit steady-state analysis covering single and poly-phase circuits with emphasis on applications like transformers, induction machines and frequency response. DC circuit analysis is used as a special case to introduce the basic components and basic analysis techniques. Primarily, students from Mechanical Engineering, Civil Engineering and Engineering Management departments take this course; it is required for mechanical engineering students who form the largest group of students every semester. Most of the students enroll in this course in their junior or senior year. Two sections of this course are offered every fall and spring semesters. The typical enrollment combined for both sections ranges from 160 to 200 students.

Motivation

Motivations to redesign this course were manifold. The large number of students posed challenges like lack of student instructor interaction with most students in the class, different learning styles of the students, different level of pre-requisite preparation and the lack of motivation of the students to take this course. This is a required course for most of the students who enroll and it was felt that they came in with a pre-bias of not liking the content and not seeing the value in learning material outside of their parent departments. Elementary differential equations and sophomore level Physics are the two prerequisites for this course. Due to different levels of use of these prerequisite courses in their parent departments, the students came in with different level of preparation in these courses.

Most of the students were unable to use the concepts learnt in their prerequisite courses and needed help, which meant that most of the concepts needed for the Circuits course, from Differential Equations and Physics, had to be covered again. This took away valuable time from covering the actual course content. This became specifically challenging considering the amount of material that has to be covered in the Circuits course. Spending valuable time on covering prerequisite material also meant speeding up the pace of the class that made the course challenging for the students since they came into this course having little to no understanding of electrical circuit concepts.

Catering to different learning styles of the students was also one of the main motivations behind changing the traditional lecture format. It was thought that providing different avenues of learning style like visual, verbal, interactive, self-paced etc. would cater to the needs of different students. Incorporating all of these learning styles was not feasible in a traditional lecture format. It was felt that providing self-paced video lessons would help students prepare for the class better and since the in-class meeting would be an extension of the video lessons, it might not be as daunting as covering new material in every single class.

In addition to above-mentioned concerns, it was also noticed that the students were not open to exploring different possibilities of a solution on their own. They were very resistant to the idea of coming up with a solution strategy on their own. They wanted their homework and exam problems to be just a different numerical version of examples covered in class, so that they could replicate the steps of solutions shown in class and pass the exams. They were only interested in learning the material for exam because there was not enough time spent in class covering the practical applications that could connect the course content to their relevant fields of work. Thus an important opportunity of invoking interest was missing.

In the traditional format of the course, the instructor would lecture for 50 minutes of the class, covering basic concepts and some examples, frequently spending time covering the pre-requisite material that might be needed. Students would either just concentrate on taking notes, not paying attention to the concepts or applications being discussed, or just loose any interest because of a short attention span. Like other circuits courses, this course also builds on material learnt in each class. So anything that was not understood in one class would lead to poor or no understanding of the material covered in later classes, amplifying the problem of limited time to cover a lot of material.

A bended learning format allows for better utility of in-class time, better preparation for students, sufficient time in the class to cover field relevant applications and eliminates the need to cover pre-requisite concepts multiple times. Providing the first introduction of the new material via video lessons allows students to have a self-paced learning environment where they can take notes, review as many time as they like and also refer back to the content whenever they need to. This is especially helpful for students who may not feel comfortable asking questions, specially based on prerequisite material, in class thus hampering their learning of the new material.

Blended format structure

The course was changed from a traditional lecture format to a blended format – a blend of flipped classroom and face-to-face class meetings. The course was changed in stages. During the first semester of testing in spring of 2017, some of the video content was introduced. During the second stage in fall of 2017, all of the intended videos were launched. Officially, the course went from three class meetings to two meetings per week in fall of 2017. Almost one-third of the material was made available to student via video lessons. The in-class meetings were changed from three 50-minute meetings every week to two 50-minute meetings every week with one lecture worth of material covered by video lessons. The students were assigned a video lesson before an appropriate lecture. Each video lesson consisted of multiple short videos. For each concept, one video is used to introduce the content to students by defining a new concept and establishing its importance and use in the context of circuit analysis. Another video lesson then covers a direct example of the concept to demonstrate its application. There are 13 learning modules in total with different number of videos in each module depending on the concepts covered. Each module has an associated quiz. Until now, the modules have been made available a week before they are due. The plan for future is to provide all modules in the beginning of the semester.

During the first semester of testing the blended format, the quizzes were not assigned. Instead the students were expected to know the material learnt from video lessons to work on their homework and in-class problems. It was found that there was a very small population of self-motivated students who actually watched the assigned lessons before designated lecture. Based on this information, the quizzes were introduced during the second semester of testing. Each lesson had an associated quiz. The quiz submissions were due before a particular lecture for which the concepts learnt from video lessons were needed. Quizzes were timed and students are offered two attempts for each quiz. For any questions that they may have answered incorrectly during first attempt, a feedback was provided prompting them to think about the conceptual or mathematical mistakes that may have made.

In order to provide multiple avenues to cater to different learning styles, the video recording of each in-class lecture was also provided to the students. This provided students an opportunity to revisit the lecture if they did not understand something in class or if they did not have sufficient time to prepare the topic. For those students who learn best by listening to the discussion in class and find note-taking to be distracting, having access to the lectures meant that they could take the notes later and focus on what they wanted to discuss and learn in the class. Figure 1 shows different learning opportunities available to the students inside and outside of class. Each week, the learning cycle starts with watching the video lessons and then taking the associated quiz. In-

class activities are built on the video lessons and the students are then assigned a weekly homework to further their understanding of the covered topic. Missouri S&T has a Learning Enhancement Across Disciplines (LEAD) program under which instructors volunteer their time outside of the class to provide tutoring or review sessions. The course under consideration has LEAD sessions of up to 4 hours per week. A Peer Learning Assistant is also available at these LEAD sessions.

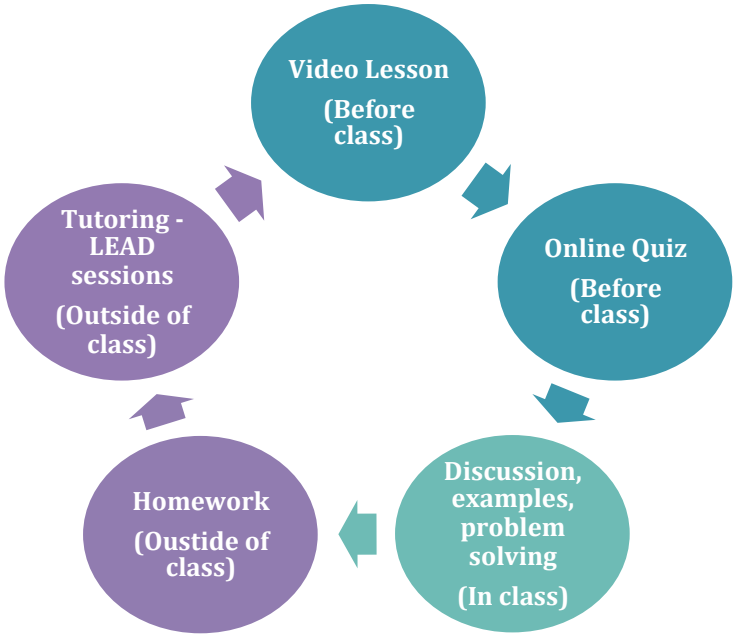

Figure 1: Course learning activities inside and outside of the class

Video lessons

20 videos were recorded in the beginning using voice over power point slides. A Wacom smart tablet and Camtasia Studio were used to record the videos. The Missouri S&T's education technology staff then edited the videos for unnecessary pauses and interruptions and added closed-captioning. During the first testing semester, it was felt that more videos would be helpful. 10 additional videos were recorded on an iPad using the Explain Everything app that allows for voice-over power point slides recording. Basic editing was also done using this app before handing over the videos to the education technology staff for professional editing and closed-captioning. Close captioning of the videos was done in accordance with The American with Disabilities Act and also for the benefit of the students and instructors who may not be native English speakers. During the editing process, copyright information was also added to the videos.

The first set of videos was primarily conceptual in nature. These videos were intended to introduce a new concept by covering definitions, new terminology, conventions associated with a specific topic, any derivation of formulae etc. and direct examples. Examples provided step-by-step solution of a concept introduced. Second set of videos were majorly geared towards

additional examples that required combining more than one concept and a slightly higher degree of complexity than what was covered in the first set of videos. Figure 2 provides an example of a slide from the video lesson on Complex Algebra. This is one of the topics that students were expected to have some knowledge of but it was found that in the traditional format, the students struggled with using complex algebra just because context of its application changed from mathematics to Circuits. Video lessons presented them with sufficient background and a connection between what they knew and how they were expected to use the knowledge in the new context. Figure 1 shows a still capture from a video lesson on Complex Algebra.

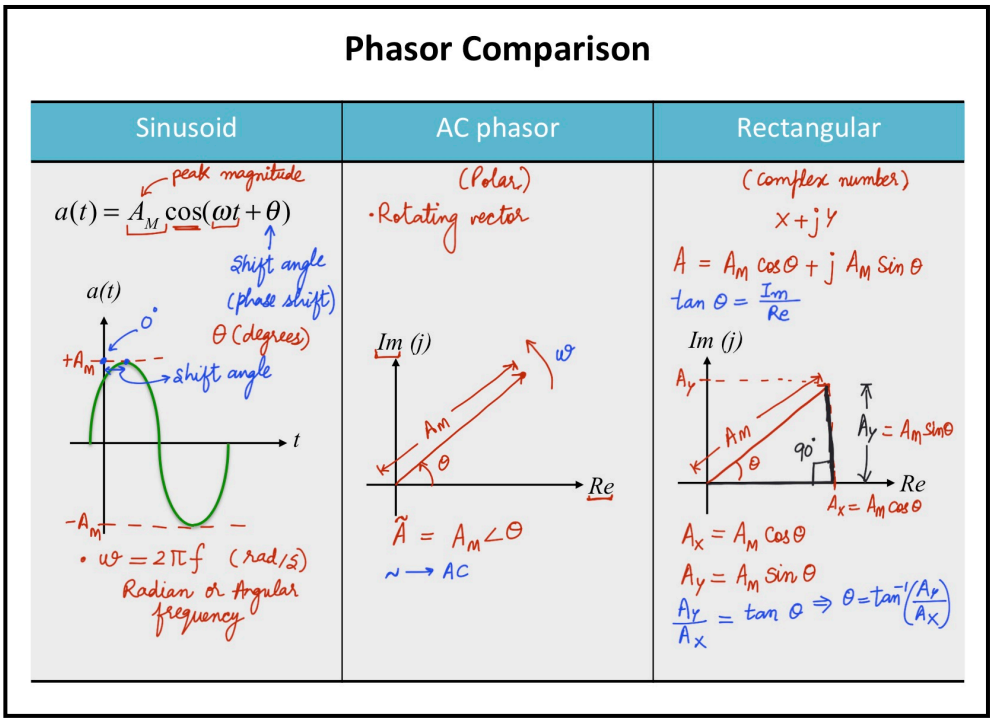

Figure 2: A still from an online lesson on Complex Algebra

Missouri S&T uses Canvas (Instructure) as the Learning Management System for all courses. The online modules were posted on canvas with all the videos in each module along with a button leading to the quiz on the single page. Quizzes were conducted and graded online using Canvas. Other recording and editing tools were used because of their availability and accessibility at the time of development of these modules. The online quizzes tested students on the material presented in each module. Each quiz had 5-10 questions based on the nature of the topic. Figure 3 presents some of the questions from the quiz associated with the AC Power Module (lesson).

Question 1 1 pts

Match the given AC power symbols (in frequency domain) with the correct type of power they symbolize.

P [Choose]

Q [Choose]

Question 2 2 pts

Which of the following are TRUE for complex power.

- ☐ Complex Power is one of the sides on a power triangle
- ☐ It is expressed in (W) Watts
- ☐ It can be expressed in polar or rectangular form
- ☐ It is expressed in (VARs) Volt-Amperes-Reactive
- ☐ It is expresses in (VA) Volt-Amps

Question 3 1 pts

A passive load consumes $60\angle 40°$ VA of complex power. Determine the apparent power consumed by this load. Express your answer in VA.

Question 4 2 pts

A passive load consumes 45 W of power; power angle for the load is -50°.

Calculate the apparent power consumed by the load. Express in VA.

Question 5 2 pts

Which of the following is/are TRUE regarding the reactive power?

- ☐ It is expressed in VAR (Volts-Amps-Reactive)
- ☐ Negative reactive power implies that load is Capacitive in nature
- ☐ Reactive power is a non-negative number
- ☐ It is expressed in VA (Volta-Amps)
- ☐ Negative reactive power implies that load is Inductive in nature

Figure 3: Some questions from the Quiz associated with lesson on AC Power

There were three types of questions used in the quizzes.

- *Conceptual:* Direct questions were used to test and reinforce the important concepts. These included questions like true or false, fill in the blank etc.
- *Direct numerical application:* Short numerical questions with low difficulty level were used. The intention with these questions was to test the students' ability to apply direct concepts and replicate problem solving covered in video lessons.
- *Association based:* For some quizzes, concept association questions were also used. These were either conceptual or numerical in nature. These questions covered material from the associated video lesson and built upon concepts learnt previously. These questions were intended for students to recall or review material that they may not have used directly for a while but were expected to use again for one of the upcoming topics. This helped specially with topics like triangles (impedance and power), peak and root-mean-square values, polar and rectangular expressions etc.

In-class lectures

In-class or in-person lecture meetings were conducted every Wednesday and Friday. The students typically had a quiz due before Wednesday's lecture and sometimes also before Friday's lecture. Lecture time was utilized by covering more examples by the instructor. The traditional structure where an instructor works on a problem to demonstrate to students was not used. Since students had already visited the material before coming to the class, a brief review of the topic was conducted to highlight the main points and the students were asked to provide the step-by-step solution to the examples undertaken in class. Students were also asked simple conceptual questions relating multiple topics to prompt them to link to previous topics that they had learnt.

Think-Pair-Share activities were used to discuss concept applications, real-world applications and other topical relevant subjects. This was to engage students in the material and to cater to different learning styles since some students might find it a lot easier to ask question from their peers rather than the instructor. The students were given time to think on their own, then share their thoughts or solutions with their peers and then with the whole class. Group problem-solving activities were also conducted frequently. These activities entailed groups of 3 or 4 students working on a problem together. Each group had only one submission to make at the end of the activity. This encouraged the students to discuss the possible methodology to apply, check any errors and in the process clarify any conceptual doubts they might have. The instructor could then move around the classroom to see the level of engagement, help students with any questions and nudge students to participate if they were not already doing so. It was found that a lot of students who generally did not ask questions in class asked questions during this process.

Comparative analysis

For both the traditional and blended format of the course, the students were given two mid-term exams and a final exam. Exam 1 was given over the material covered until that point in the semester; exam 2 was given over the material covered after exam 1 leading up to the exam 2 and the final exam was comprehensive. Figures 4, 5 and 6 show a comparison of mean scores in exam 1, exam 2 and the final exam over different semesters, respectively. On x-axis, the notation SP is used to indicate a spring semester and FS is used to indicate a fall semester. The Y-axis

presents the mean scores in terms of percentages acquired. A traditional lecture format was used for the course in spring semesters of 2015 and 2016, some video content was introduced in spring of 2017 but the 3-class meeting format still remained. Fall 2017 and spring 2018 semesters used the blended format as intended. The semester terms that are compared here were chosen for the same instructor and similar content delivery. The number of topics covered was higher in the blended format. For the topics that remained the same, it was observed that the extent of discussion and depth of coverage was considerably more in blended format.

Upon changing the class structure to blended, the students did significantly better in the final exam as shown in figure 5 but exams 1 and 2 performances did not follow the same trend. Exam 1 scores either remained about the same or slightly lower than the traditional format and exam 2 scores remained about the same or slightly higher. There are various changes from one semester to the next in terms of mix of students, number of students, slight variations in the amount of material covered in each exam etc. So it is not possible to do a fair and apt comparison of performances. Generally, it was found that the reduced in-class time did not have a negative impact on the student exam performances.

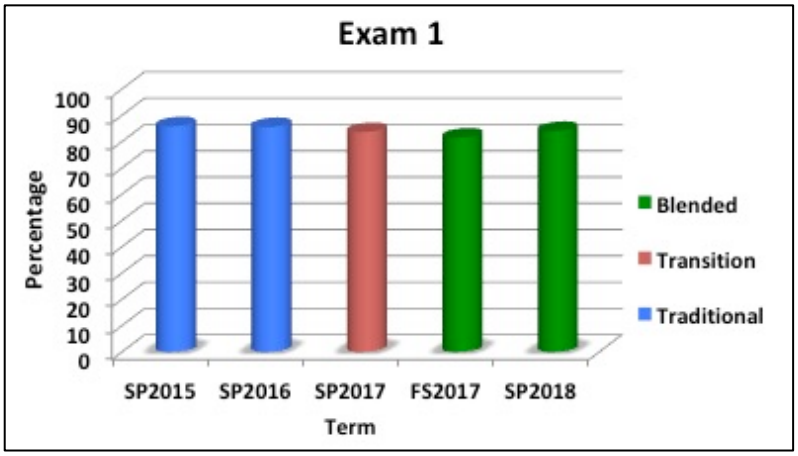

Figure 4: Exam 1 performance by semester

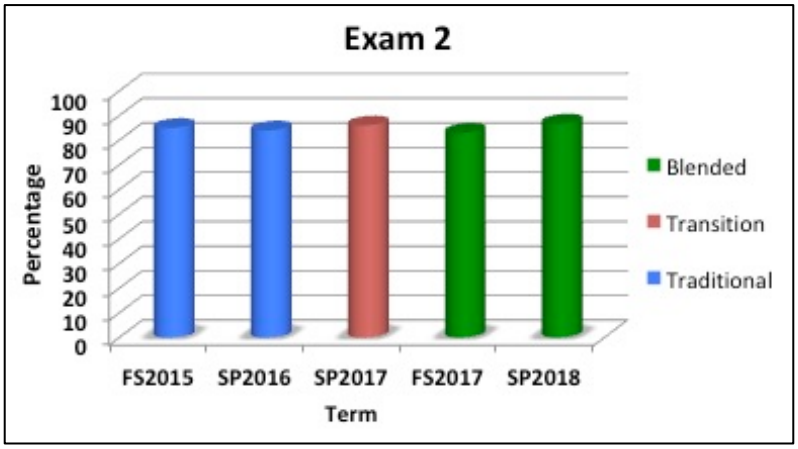

Figure 5: Exam 2 performance by semester

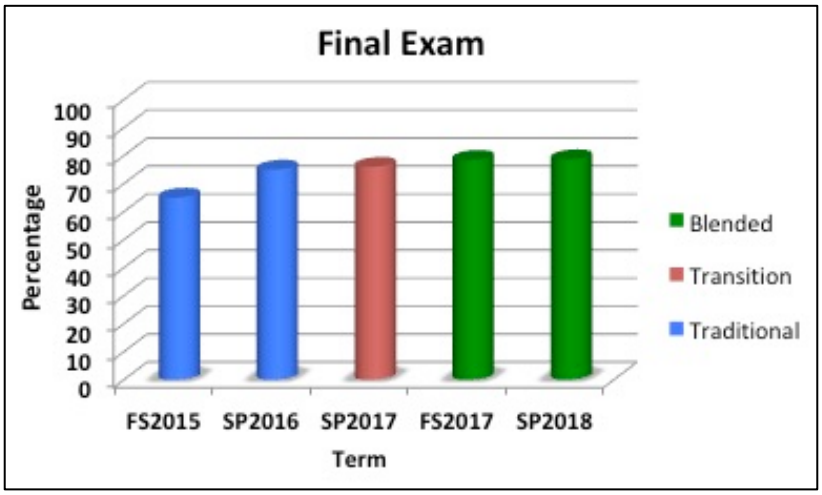

Figure 6: Final exam performance by semester

The teaching effectiveness of the instructor based on end-of-semester student evaluations improved significantly. Figure 7 shows the comparison between student satisfaction levels between spring semesters of 2015 (traditional) and 2018 (blended). More students also thought that the course had better than average educational value to them. Figure 8 shows the comparison of the student responses towards their perceived education value of the course to them for spring semesters of 2015 and 2018.

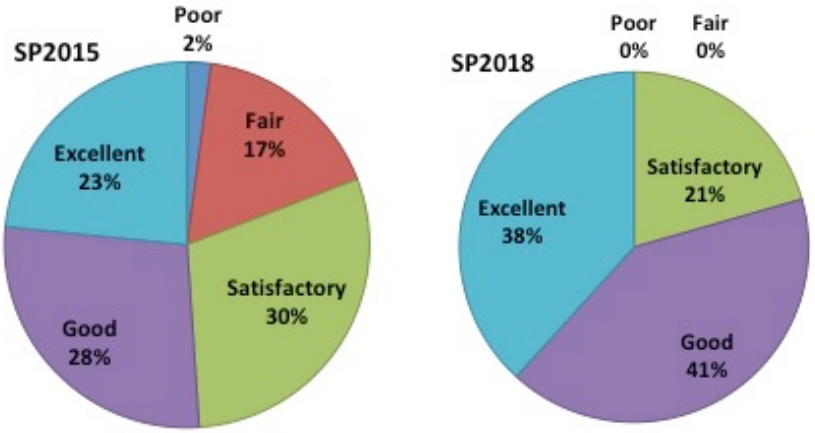

Figure 7: Teaching effectiveness of the instructor

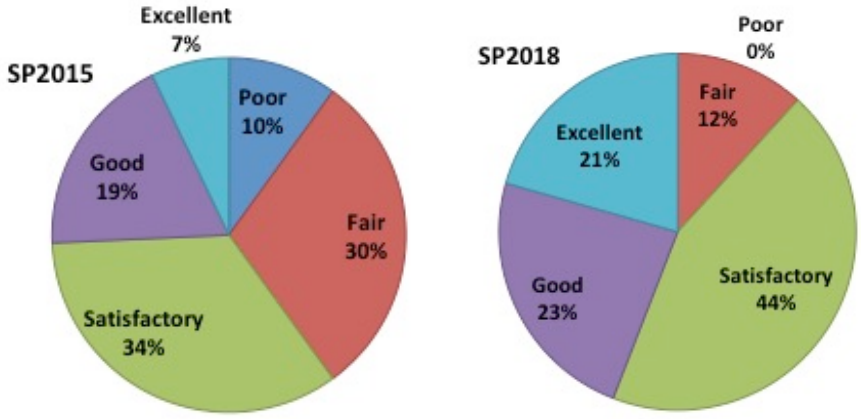

Figure 8: Educational value of the course to the students

Student feedback

Table 1 presents the feedback collected via a survey of students in the spring 2018 class. The survey is still open and more responses might be available by the time of final submission of this paper. In future, it is planned to add more questions to the survey to find out about what prior experience of an alternative classroom the students' may have had before taking this class. 30 students have responded so far and the results for 8 of the questions are tabulated in Table 1. Two of the survey questions asked students to specifically list the aspects of the blended format that they liked and aspects that they were not particularly happy about.

Generally, the students liked access to the video lessons, they particularly thought that self-paced nature was helpful in their learning, and most of them used the video lessons multiple times. The students also liked having access to the lecture recordings for the purpose of revisiting the lecture for review or note taking. The length of some of the videos and quality of one of the videos in particular were not satisfactory. Almost one-third of the respondents concurred that some of the modules with multiple videos were too long. Even though some of the additional examples were intended as the supplemental or optional material, failure to identify the material as such led to the students identifying the supplemental material as part of the required assignment. In future, any supplemental material will be provided separately outside of the online modules so that the students can refer to these examples only when they need additional help.

The responses of the students for the two text questions are listed below. All of the respondents did not provide comments for the questions and some only provided comments for one of the questions. Some of the reoccurring responses are listed below as submitted by students with number of reoccurrences of same or similar responses indicated in parentheses next to each response.

Question 9: What were some of the positive aspects of Blended Learning format in EE2800?

- "More material to review for exams"
- "Could access it anywhere, anytime" (2 other similar responses)

- “Liked having recordings of in-class lectures”
- “Easy points, ability to pause lecture to go at your own pace when taking notes, easily accessible.” (5 other similar responses)
- “There is less time in the classroom while still learning the same amount of material.”
- “ I liked that the blended learning required you to do more outside of lecture and helped you to "pre-learn" the material so that you could come to the next class period prepared with any questions.”
- “Only met twice a week and I like being able to have control of when I would like to watch the lecture.” (2 other similar responses)
- “Learning some concepts prior to the formal class time made retaining new material easier.” (3 other similar responses)
- “Provided multiple opportunities to learn the information; went slower than in class lectures; provide a base for that weeks material.” (2 other similar responses)
- “Helped prepare me for the in-class lecture and solidified concepts. Provided additional examples for homework.”
- “The quizzes definitely helped me to learn the content and you provided good feedback when we answered wrong. It also was nice that since we had 2 attempts, there wasn't as much pressure and it was a safe environment to attempt the question without getting punished right away.”
- “The topics covered outside of class were very manageable. They were not too difficult to understand and were further explained in class.”

Question 10: What were some of the negative aspects of Blended Learning format in EE2800?

- “Videos were very long sometimes” (9 other similar responses)
- “It was difficult to watch them on my own”
- “A lot of times the info given was then repeated in class” (2 other similar responses)
- “Had to make up the lecture online, would have rather just had in-class lectures 3 times a week”
- “The only negative was that some of the videos were fairly long and took much longer than a lecture period, granted I was the type of student that paused for notes when needed (frequently) to get all of the material.”
- “Some videos had long pauses or could have been edited better.”
- “N/A I absolutely loved it and I feel that if we didn’t have the blended learning I probably wouldn’t have earned my A”
- “Maybe make the quizzes due by class time not 8am”
- “A couple of the online quizzes were a little long”

Table 1: Survey Data collected from Spring 2018 students

Questions	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I prefer the blended instruction better than the traditional lecture format	7	10	7	5	1
The blended format required too much time outside of the class considering it was designed to replace one lecture period (per week	1	6	3	14	6
The online material was easy to access	18	12	0	0	0
I liked the format of the online lessons	11	11	7	1	0
Completing the online lessons and quizzes before coming to class helped me in better understanding the material	11	13	3	3	0
I would recommend this course (in blended format) to my friends	11	12	5	2	0
	Too long	About the right length	Too short		
The length of the videos was generally	8	22	0		
	Learning new material	Reviewing the material for exams	Reviewing the material for HW	Other	
I used the online video lessons for (select all that applies)	25	17	23	1	

Conclusion

The adoption of blended format for the Electrical Circuits for non-EE majors course at Missouri S&T was successfully implemented. The student feedback of the experience was generally positive; the only negative feedback was in terms of the length of some of the modules. The efforts are already underway to address the issue and to create shorter modules that comprise of fewer videos. Overall, the performance of the students as evaluated by their performance in the

exams was not negatively impacted. It is difficult to conclude whether any improvements in the exam performance were due to change in the lecture format alone. There are a number of factors that impact student learning; nature of the content delivery is one of the important factors. Other factors include experience of the instructor, student perception of the content, ability of instructor to connect the material to the student's vision of their future career path etc. These additional features could or could not impact the change in lecture format but this instructor feels that there was definitely a positive impact of adopting the blended learning format.

The format was not only helpful for students by providing self-paced learning that aided their understanding and prepared them for the classes better but also allowed more in-class time for the instructor to discuss topics in-depth and to bring in the real world examples. These opportunities provided frequent and better interactions in class between students and the instructor. The instructor experienced a change in the student perception about the course; the number of student who showed enthusiasm about the course outside of their major has grown over the last couple of years. Exam performance is of course not the whole picture of the student learning experience but it is a good tool to measure the impact of changes in lecture format to a certain degree.

In conclusion, blended learning or partially flipped classroom structure offers a great opportunity to address challenges like covering a lot of material in limited time and motivating students about the subject matter that could be very mathematical. A streamlined blended learning approach frees class time for more discussion of real world applications, providing students with a direct link to their respective fields. Students come prepared to class leading to better interactions and discussions in class resulting in better learning outcomes. With changing classroom diversity, there is an emerging need to cater different learning styles and needs of students. The field of engineering and technology is ever changing and if we do not reflect that change in our classrooms, we cannot demand the attention and motivation of our students. As educators, it is our responsibility to respond to the changing needs of our classrooms and cater to as many different learning styles as possible.

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