Work-In-Progress: Incorporating Active Learning and the Entrepreneurial Mindset into a First Level Electrical Circuits Course

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Introduction

This work-in-progress paper investigates the effects of an alternative instructional format in teaching a first level electrical circuits course with a lab component. The research for this paper centered around implementation of a flipped classroom design. The flipped model has gained popularity in recent years based largely on the promise that such structural modifications will allow instructors to move coverage of critical background information out of classroom time, allowing more innovative, problem-based, and active learning activities to take place in the classroom [1]. Despite the potential benefits of flipped course design, many engineering classes, and engineering as a whole, still lag behind their non-STEM colleagues in successfully implementing the flipped model of instruction and research on flipped models within early courses (including circuits) remains limited [2].

With this backdrop, beginning in the spring of 2017, a sophomore-level electrical engineering course, Circuits I, was taught at Arizona State University. This fifteen-week, four-credit course is many students' first exposure to the application and analysis of electrical networks. The concept of analyzing electrical circuits provides a foundation for courses in various majors and is therefore fundamental to a diverse student population. The course has traditionally followed a teacher-centered model of instruction with the underlying expectation that students independently review reading materials before the lecture. There was typically little encouragement of group work, peer-to-peer interaction, or active learning opportunities, other than those taking place in the lab portion of the class. The lab included following instructions to make specific circuits and taking measurements.

Changes to this model were introduced into sections of the course over the last three academic years, however, all sections were led by the same instructor. The first course modification was the inclusion of additional active learning. In one section of the course, the amount of lecture time was reduced allowing more time for group work on examples that reinforced important concepts. The in-class examples were redesigned to encourage peer-to-peer interaction, promote exchange of ideas and questions, and provide connection between the lecture material and examples. In another section, the class was modified to include a flipped course approach. Students were required to view lecture videos prior to attending class sessions, in-class lecture was further reduced to the key points, and more time was used for active learning in the classroom.

Student-level data was collected for all sections of the course and included student major, course and exam grades, and gender. The data was used to answer two primary research objectives. The first was to analyze data from the alternatively designed Circuits course sections to determine if students enrolled in flipped course sections experienced improved achievement and lower DEW rates (the percentage of students scoring a D, E, or withdrawing from the course). The second research objective was to determine, more specifically, if there were any observable improvements in student achievement based on gender when flipped classroom techniques were introduced. This work-in-progress paper begins to address the research objectives and outlines a path forward for additional necessary research.

Background and Relevant Literature

Flipped Learning in Engineering

As noted above, the flipped course design has grown in popularity over the last decade, and, while engineering has been slower to adopt these practices than other disciplines, there has been a significant increase in the amount of research surrounding the potential of flipped classroom models in recent years [2]. Flipped learning leverages best practices from active learning and centers on the idea that students need to be provided with opportunities to actively engage in the learning process rather than sitting as passive observers during lecture, or, worse yet, relying on rote memorization for knowledge acquisition [3]. Flipped learning often leverages videos or technology to present the 'lecture' concepts outside of the classroom, allowing more in-class time to be spent on activities, discussion, and guided practice. Faculty often view flipping as a viable solution to the challenge of covering content while still including evidence-based active learning instructional strategies [4].

Despite the interest in flipping as a potential solution to engineering instructional challenges, there are relatively few studies available with quantitative statistical analysis of student outcomes and achievement reported [5]. There also remains a need for additional research on best practices for effectively implementing flipping, particularly in circuits courses. Common flipping challenges including supporting students through technical difficulties, disinterest in required pre-work, and greater understanding of instructional strategies that benefit underrepresented groups of engineering students remain areas for future study as well.

Entrepreneurial Mindset

Throughout engineering education, work is being done through KEEN (the Kern Entrepreneurial Engineering Network) to develop Entrepreneurial Mindset (EM) skills [6]. EM incorporates the principles of the 3C's (curiosity connections, and creating value) to help students think critically about stakeholder needs, to communicate to a range of audiences in various contexts, and to use their technical skills to navigate complex systems. There is an inherent benefit to pairing technical skills with the ability to add and recognize value, as is built into the Entrepreneurial Mindset framework. The Entrepreneurial Mindset principles of the 3C's integrated into the course, increases student engagement and as research shows, strong emotional associations for the learner and relationship to the learner's interests, goals, and past experiences increase the chance of long-term memory storage [7]. Also, as technologies that students are exposed to continue to be more complex, prior interaction with circuits rarely occurs, so students enter their first circuits course without any inherent intuition [8]. This study includes the use of EM in a first year circuits course to verify that EM reinforces the understanding of complex engineering concepts, helps students to relate to the material, and is more inclusive to various learning types and backgrounds [9].

Methodology

The Circuits I course is a requirement during the sophomore year for a number of engineering disciplines within the university, including electrical engineering, mechanical engineering, aerospace engineering, civil engineering, biomedical engineering, and computer systems engineering. The course consists of a 3-credit-hour lecture and a 1-credit hour lab. This study looks at 4 sections, with 228 students, taught in 4 ways by the same instructor using the same presentation and assignment materials.

All of the 4 sections utilized an interactive tutorial system for linear circuit analysis [10] and textbook problems for homework assignments and the lab portion all of the 4 sections was the standard follow instructions to build circuits and take measurements approach. The first section in the spring of 2017 (n = 63) followed a traditional lecture methodology. The students were expected to read specific chapters of the textbook before attending lecture, and during the lecture, the materials were explained in more detail, examples were worked through by the instructor, and quizzes were modified to be group work and peer instruction [11], rather than assessment tools. The second section in the spring of 2018 (n = 31) and the third section in the spring of 2019 (n = 68) mostly followed the traditional lecture methodology, but with some increased in-class activities, including time for students to work through specific example problems themselves and group in-class assignments where the students could interact with each other to work through the problems. The fourth section in the spring of 2019 (n = 66) utilized a flipped classroom approach, where the pre-class textbook readings were supplemented with short (10-15min) pre-class video lectures, and a 5 question multiple choice pre-class quiz to verify that the videos had been watched. The in-class time for the fourth section consisted of a shorter lecture, focusing on the key points, followed by instructor-led examples, time for the students to independently work through examples (with instructor and TA support), and group work.

The current course structure continues this study with the addition of a project based lab and course analogies and an analogy reflection assignment, all of which incorporate the concepts of Entrepreneurial Mindset. To account for the differences in students, some controls were taken into account, including the same instructor, the same practice and application materials, the same lab and the same textbook readings for all 4 sections. The 4 sections were also all during the Spring semester and roughly the same time of day (mid-morning/early afternoon). A comparison between the 4 section course structures that the data is gathered from and the current course structure is shown below in Figure 1.

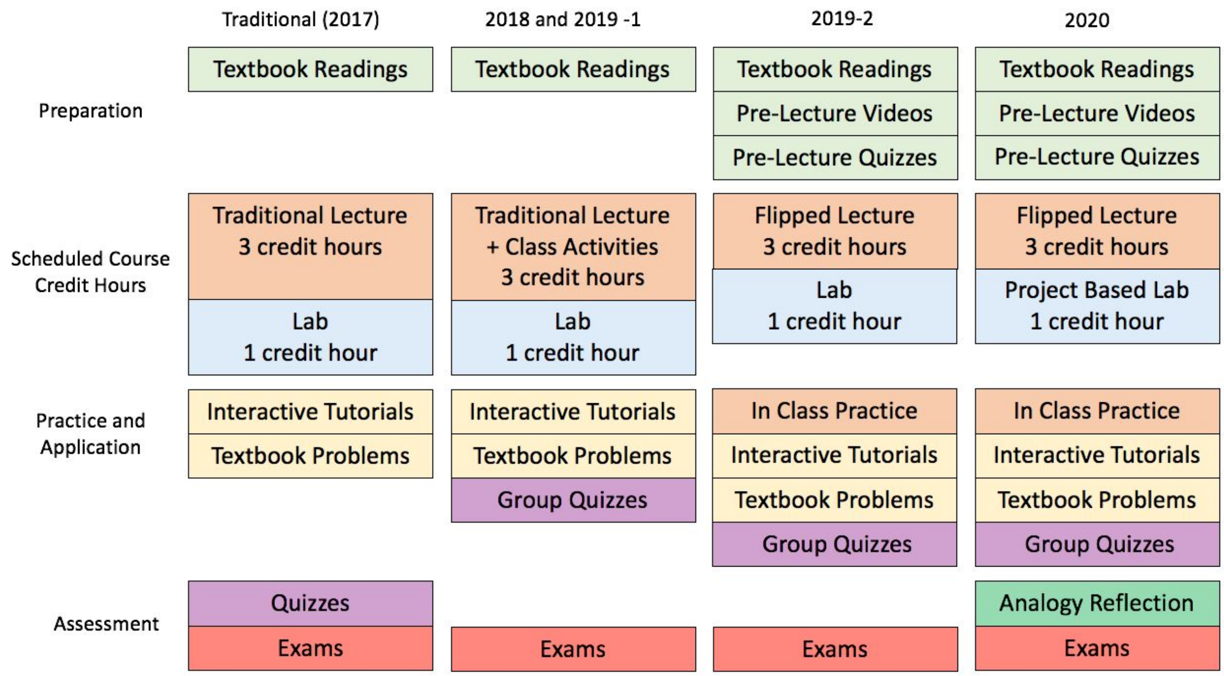

Figure 1: Course structure comparison between the 2017 and 2020 versions of the course.

The research question driving this idea and further course adaptations is whether active learning and Entrepreneurial Mindset would provide significantly higher learning gains compared to students in the traditional sections and specifically the impact on non-electrical engineering majors and women.

Data Sources

The primary data source for this study came from the course gradebooks for each section. Although students were enrolled in multiple sections of the course, the data collected and reviewed was the same for all students and allowed the results to be easily compared. Each section had two midterm exams and a final exam that covered the same material from the course. All of the exams were graded by the same instructor and the instructor entered the grades into the gradebook, from which the data for this research was extracted. Table 1, below, summarizes the student data that was available. Only exam grades and final course grades were analyzed across the 4 sections and before conducting analysis, all of the student data was dissociated from the information.

Table 1. Student Data Summary

Item	Number	Maximum Points Per Item	Total Points	% of Final Grade
Quizzes and Assignments	35	10	350	20%
Labs	9	100	900	20%
Midterm Exam	2	100	200	30%
Final Exam	1	100	100	30%

Data Analysis & Results

Individual classroom components were examined to assess for differences between the student outcomes between the four cohorts of students. A breakdown of the average course components and results of z-score analysis of variance tests are presented in table 2 below.

Table 2. Average Score of Course Components & Significance

	Average Scores							
Course Component	**Section 1 (2017) Traditional**	***Sig. of Samples (P-Value)***	**Section 2 (2018) +Class Activities**	***Sig. of Samples (P-Value)***	**Section 3 (2019-1) + Class Activities**	***Sig. of Samples (P-Value)***	**Section 4 (2019-2) Flipped Course**	***Sig. of Samples (P-Value)***
Midterm 1	73.93	*0.47*	56.34	*0.15*	78.99	*0.58*	81.3	*0.63*
Midterm 2	89.11	*0.75*	61.95	*0.25*	69.32	*0.38*	75.21	*0.49*
Final Exam	70.53	*0.51*	68.48	*0.48*	65.79	*0.43*	73.66	*0.57*
Final grades	80.9	*0.5*	76.88	*0.4*	80.11	*0.48*	83.71	*0.57*

Across the first midterm exam for all sections, the students in the 2019-2 section had the highest average score (81.3/100), followed by the 2019-1 students (78.99/100). However, the data sets were not significant over the four course sections ($p > 0.05$).

Across the second midterm exam for all sections, the students in the 2017 section had the highest average score (89.11/100), followed by the 2019-2 students (75.21/100). However, the data sets were not significant over the four course sections ($p > 0.05$).

Across the final exam for all sections, the students in the 2019-2 section had the highest average score (73.66/100), followed by the 2017 students (70.53/100). However, the data sets were not significant over the four course sections ($p > 0.05$).

Analyzing the final grades for the course across the sections, the students in the 2019-2 section had the highest average score (83.71/100), followed by the 2017 students (80.9/100). However, the data sets were not significant over the four course sections ($p > 0.05$).

Since the average grades across the sections did not show improvements that were statistically significant, the grade distributions across the four sections were evaluated, with a focus on the non-electrical engineering majors and female students. Table 3, below, presents the distribution of final grades across the 4 sections and results of the chi-squared tests are presented.

Table 3. Grade Distributions, by Instructional Type

Section	% A/A+	% B	% C	% DEW	*Sig. of Samples (P-Value)*
Section 1 (2017) Traditional	31.43%	21.43%	21.43%	25.71%	*0.12*
Section 2 (2018) +Class Activities	27.27%	27.27%	21.21%	24.24%	
Section 3 (2019-1) + Class Activities	35.21%	22.54%	21.13%	21.13%	
Section 4 (2019-2) Flipped Course	30.43%	34.78%	21.74%	13.04%	

Examining the differences in grade distributions across the different sections, is appears that the grade distributions of the highest (A/A+), above average (B), and average (C) achievements were not significantly different over the fours sections, but the section 4 students had the lowest DEW percentage at 13.4%. The data sets were more marginally statistically significant ($p > 0.05$). Figure 2, below, graphically shows the grade distribution over the 4 course sections.

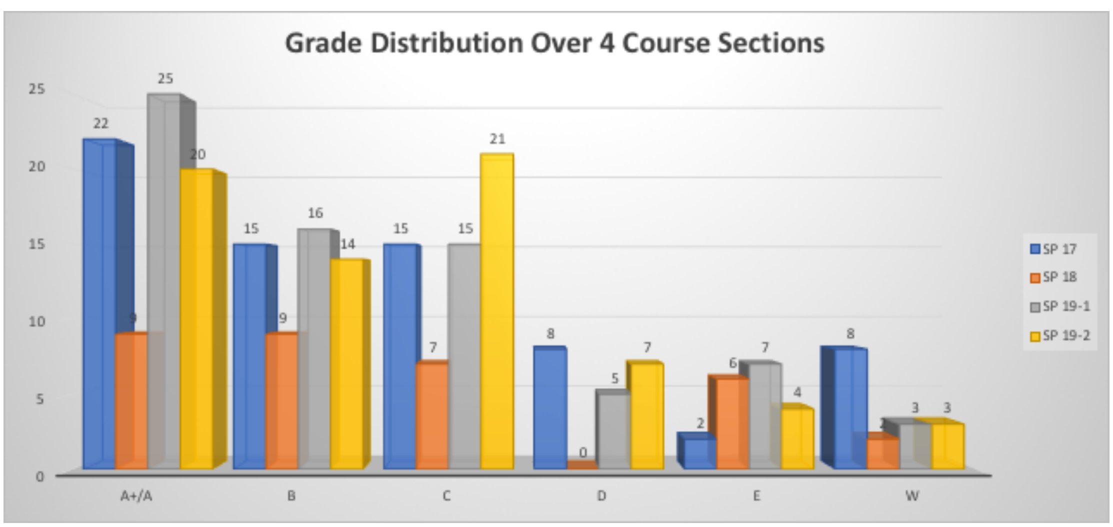

Figure 2: Grade distribution of all students over the 4 course sections of Circuits I.

Table 4, below, presents the distribution of final grades across the 4 sections focusing only on female and non-electrical engineering majors and results of the chi-squared tests are presented.

Table 4. Grade Distributions of Females and Non-EE Students, by Instructional Type

Section Females Only	**% Females**	**% A/A+**	**% B**	**% C**	**% DEW**	***Sig. of Samples (P-Value)***
Section 1 (2017) Traditional	20.00%	28.57%	14.29%	7.14%	50.00%	*0.0301*
Section 2 (2018) +Class Activities	18.18%	33.33%	0.00%	33.33%	33.33%	
Section 3 (2019-1) + Class Activities	28.17%	50.00%	35.00%	15.00%	0.00%	
Section 4 (2019-2) Flipped Course	24.64%	35.29%	29.41%	23.53%	11.76%	
Section Non-EE Only	**% Non-EE**	**% A/A+**	**% B**	**% C**	**% DEW**	***Sig. of Samples (P-Value)***
Section 1 (2017) Traditional	90.00%	31.75%	22.22%	23.81%	22.22%	*0.0761*
Section 2 (2018) +Class Activities	84.85%	25.00%	28.57%	21.43%	25.00%	
Section 3 (2019-1) + Class Activities	85.92%	32.79%	22.95%	21.31%	22.95%	
Section 4 (2019-2) Flipped Course	91.30%	30.16%	34.92%	22.22%	12.70%	

Examining the differences in grade distributions across the different sections for females only, it appears that the grade distributions of the highest (A/A+), above average (B), and average (C) achievements were not significantly different or did not change in any particular pattern over the fours sections, but the section 3 students had the lowest DEW percentage at 0% followed by the section 4 students at 11.76%. The data sets were statistically significant ($p < 0.05$). Examining the differences in grade distributions across the different sections for non-electrical engineering students only, is appears that the grade distributions of the highest (A/A+), above average (B), and average (C) achievements were not significantly different, but the section 4 students had the lowest DEW percentage at 12.70%. The data sets were marginally statistically significant ($p > 0.05$). Figures 3 and 4, below, graphically shows the grade distribution over the 4 course sections specifically for female students and non-electrical engineering majors.

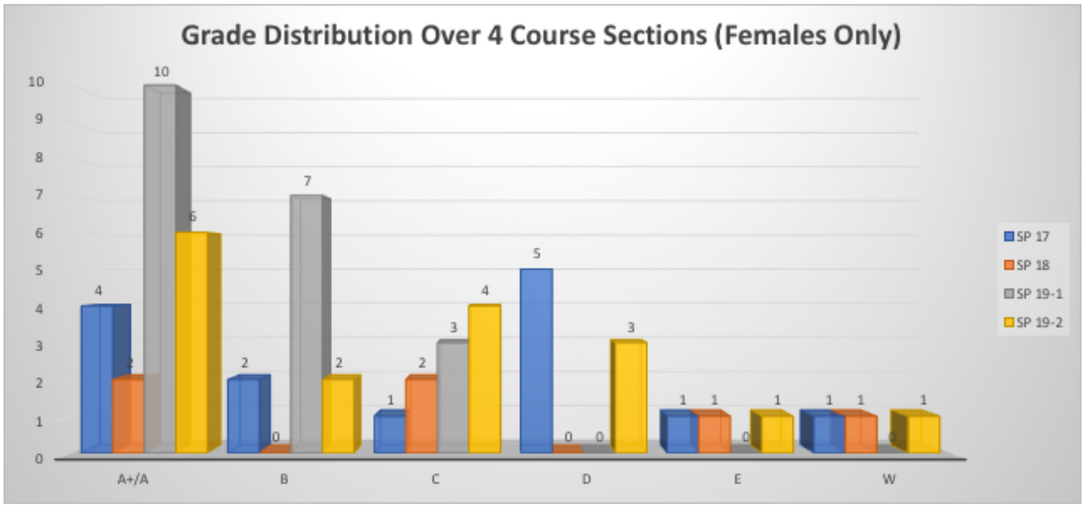

Figure 3: Grade distribution of female students over the 4 course sections of Circuits I.

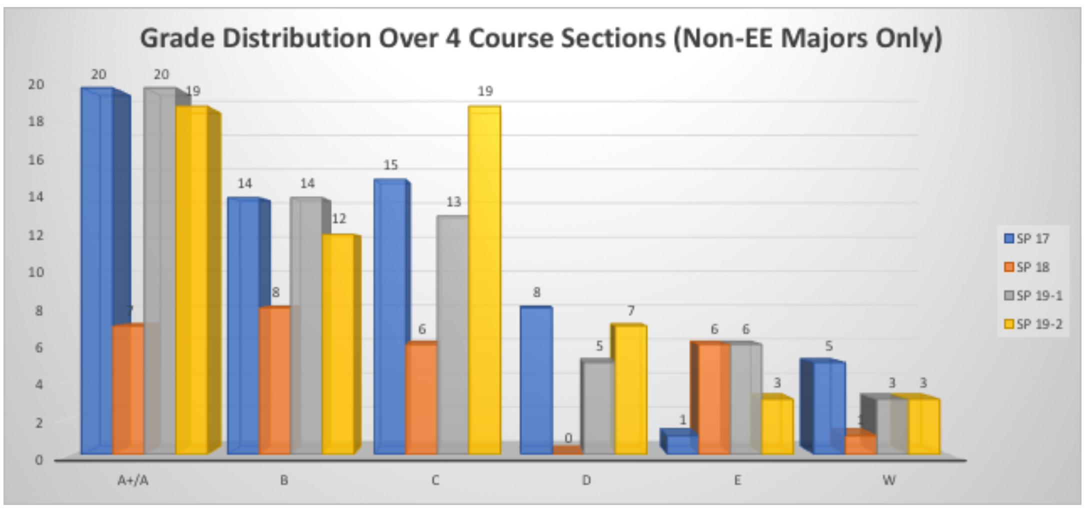

Figure 4: Grade distribution of students not majoring in electrical engineering over the 4 course sections of Circuits I.

Discussion

The main objectives of this study were to: (1) answer research questions regarding alternatively designed Circuits course sections to determine if students enrolled in flipped course sections experienced improved achievement and lower DEW rates, (2) determine, more specifically, if there were any observable improvements in student achievement based on gender when flipped classroom techniques were introduced, and (3) determine the starting point for further research on using the flipped course structure, active learning methods, and the entrepreneurial mindset in designing a Circuits I course. The data collected from this study has shown that increased active learning and increased peer-to-peer interaction has improved overall exam and final course average scores and has decreased the percentage of students scoring a D, E, or withdrawing from the course. The data further supports a direct connection between the decrease in DEW rates for female students and students not majoring in electrical engineering when implementing active learning and the flipped course design. As each change to the course has been incremental, the gains have been small, but trending in the right direction.The initial data from this study is not conclusive, as the statistical significance for many of the gains is not at the desired level ($p < 0.05$), but this research serves as a solid starting point. Since there were observable improvements in students achievement in Circuits I using active learning and a flipped course design, especially for female and non-electrical engineering majors, the next step is to outline the future course changes and further study the impacts on students. Although no formal surveys were conducted at this time, the overall anecdotal feedback from students regarding the active learning and flipped classroom was very positive and will be added to the information collected in future sections.

Future Plans

The major limitation of this study is that it is very early in the research process. The initial intention of the work that's been done, was not designed for research purposes, but the evidence that the strategies are effective based on the course averages and DEW rates shows great promise and helped frame what changes will be made next and what data will be collected. The next study will still include exam and course averages and DEW rates and also additional data including pre and post technical knowledge, ethnicity, socioeconomic status, and pre and post student perspectives will also be collected. In addition to including active learning and a flipped course design, some additional changes that will be researched are:

- Better defined learning outcomes to help connect students to the reasons for learning the various principles and methods, with focus on growth mindset versus fixed mindset.
- Project based labs. Based on the principles of Entrepreneurial Mindset, this could increase curiosity in the subject and allow students to connect the lecture material more directly to application. The project based lab will also include sub-labs that allow students to learn through failure without grade impact to help solidify understanding and build more electrical intuition.
- More in-class examples and active learning that relate directly to the project based lab and to the interests of the students, further promoting curiosity and connection.
- The use of analogies in explaining complex concepts and using reflections on the analogies as a method of assessment, again, incorporating the concepts of Entrepreneurial Mindset.

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