Can a First-year Professor be More Successful with a Flipped Classroom than with a Traditional Classroom?

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Abstract

We assessed the impact of the flipped classroom model on a first year faculty member's performance. In the fall semester, the first year faculty member was responsible for teaching two sections of a junior-level, required class: ECE-360 / Signals and Systems (3 credits). The class has historically been taught in a traditional lecture format. In the spring semester, the first year faculty member was responsible for teaching two sections of another junior-level, required class: ECE-322 / Embedded Microcontrollers (3 credits). The class has historically been taught in a flipped format. First, the first year faculty member's student performance on the ECE-360 (traditional format) and ECE-322 (flipped format) final exams were compared. Our results show that the first year faculty member's student performance moved from a uniform distribution (traditional format) to a truncated normal distribution with a higher mean (flipped format). Second, the first year faculty member's student performance on the two final exams was compared with previous years' student performance. Our results show that the first year faculty member's student performance in ECE-360 (traditional format) were more poorly distributed with a lower mean than previous years. However, in ECE-322 (flipped format) the first year faculty member's student performance distribution and mean were commensurate with performance from previous years. Third, student surveys and faculty interviews were conducted. From our analysis, we find strong quantitative and qualitative evidence that the first year faculty member was more successful teaching in a flipped mode classroom. Additionally, the improvements in student performance seen in the flipped classroom required less preparation on the part of the first year faculty member, leading to higher levels of faculty and student satisfaction.

Introduction

While there is not an official definition of what a flipped classroom is, one of the most straightforward is: "[A flipped classroom] means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa." [1] With a flipped classroom students are required to prepare for class by participating in an assignment or learning activity (such as information transfer usually reserved for a traditional lecture) before coming to class. Therefore, when students are in their flipped classroom, the time can be dedicated to a more meaningful exchange with the instructor and higher levels of learning can be achieved through individual or group problem based learning activities.

Interest in flipped classrooms has been increasing over the last several years. The use of flipped classrooms has also sparked a significant amount of research. The authors of [2] identified twenty-four different studies related to flipped classrooms. Such research work, however, has focused primarily on the potential benefit for students, and little work has been done on the benefits of flipped classrooms for faculty — especially first year faculty.

New engineering faculty are under increasing pressure to teach successfully in the classroom in their first year of academia. Different methods have been employed improve success of first year faculty [3, 4]. However, there has been minimal research into the possibility of first year faculty using a flipped classroom model to improve their teaching effectiveness. The flipped classroom model offers many advantages for student engagement and active learning [2, 5], but for first year faculty, the flipped classroom pedagogical model is often unfamiliar. In an attempt to understand how a flipped classroom might affect a first year faculty member's teaching, Valparaiso performed an experiment in the 2015–2016 academic year. A first year faculty member having no prior experience with a flipped classroom, taught classes using both traditional and flipped classroom models to determine if a first year professor can be more successful with a flipped classroom than a traditional classroom.

The remainder of the paper is divided into the following sections. Section 2 provides a brief literature review of flipped classrooms and highlights the lack of work focused on any faculty benefits. Section 3 presents the previous work at Valparaiso University in preparation for this first year faculty member flipped classroom experiment. Section 4 describes how the experiment was conducted with a flipped classroom and a traditional classroom control. Section 5 presents the results of the experiment. Section 6 provides the analysis of the results. Finally, Section 7 presents the conclusions of the experiment.

Background

In 2014-2015, over 1,000 faculty were surveyed as to their understanding and use of flipped classrooms [5]. There is not a consensus on the definition or implications of flipped classrooms:

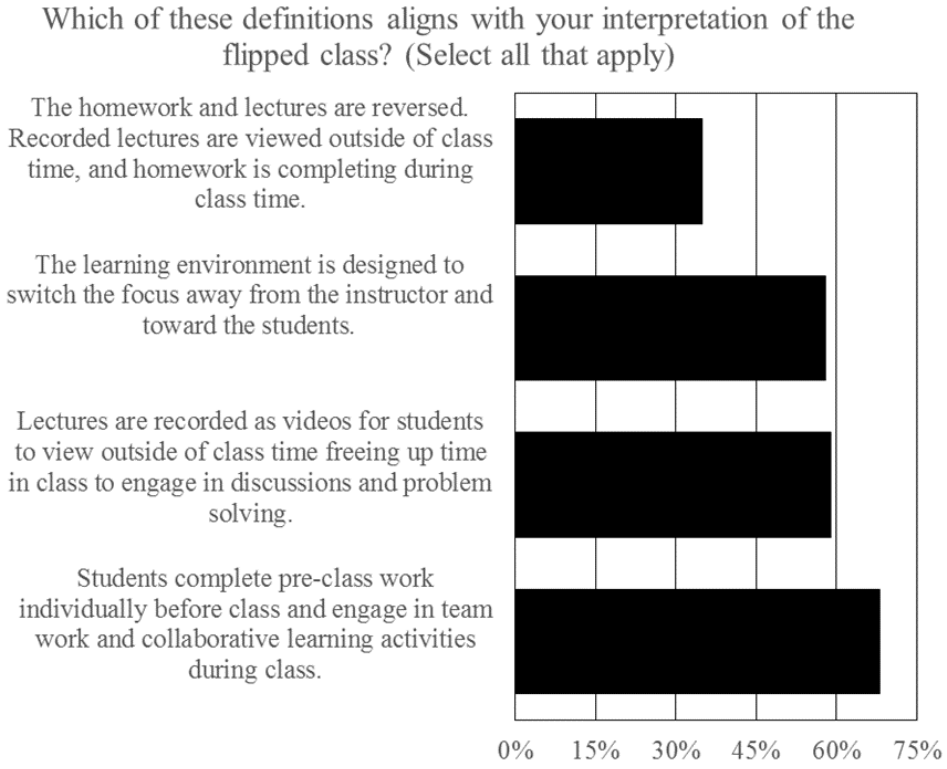

Figure 1. Survey Results of 1,084 Faculty on their Interpretation of "Flipped Classroom" [5].

Therefore, let us recall the definition of a flipped classroom from the Introduction:

"[A flipped classroom] means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa." [1]

Within this broad umbrella, a significant amount of research has been conducted to determine the efficacy of flipped classrooms on student success. The research, however, has almost unilaterally examined the *student benefits* of flipped classrooms without investigating how *faculty* might benefit from flipping their classrooms.

Previous Work

At Valparaiso University's College of Engineering, ECE-360 (Signals and Systems) is a required class for electrical engineering and computer engineering students and typically taken during the junior year. The three credit class has been taught for the past eleven years in a traditional lecture format. The course content has been substantially prepared for faculty members, and faculty teaching the course are provided by the ECE Department with a complete set of well-prepared lecture materials including presentations and examples, copies of all the past-years' previous assignments, and copies of all the past-years' previous exams. These materials provide faculty with excellent resources to teach the Signals and Systems class in a traditional classroom environment.

At Valparaiso University's College of Engineering, ECE-322 (Embedded Microcontrollers) is a required class for electrical engineering and computer engineering students and typically taken during the junior year [6]. Since 2014 the class has been taught in a mixed-mode format. Students typically receive a brief (3-8 minute) opening lecture and then work individually or in self-selected pairs on a directed active learning assignment as faculty and lab assistants employ a "teaching by walking around (TBWA)" philosophy. By implementing TBWA, faculty can interact with every student in the class in an informal manner as each student / student-pair work at their own pace. Students receive individual attention and can receive immediate feedback as they work.

During the ECE-322 annual continuous improvement cycle, it was suggested that the existing mixed-mode format and TBWA style could easily be adapted into a MOOC [6]. In turn, the MOOC could serve as an interactive textbook that integrates many components such as readings, video lectures, homework assignments, self-assessments, quizzes, laboratory projects, and social networking into a stand-alone platform. With a small grant from Texas Instruments and technical support from element14, the MOOC was launched in October, 2015. At this time, the MOOC has over 2,200 paid students from 87 countries with an all-time average student rating of 4.51/5.00.

Proposal

The research question this paper addresses is "Can a first year professor be more successful in teaching with a flipped classroom than a traditional classroom?" To learn if a first year professor can be more successful in a flipped classroom, a first year professor at Valparaiso University was

tasked with teaching two sections of ECE-360 (traditional format) in the fall semester and two sections of ECE-322 (flipped format) in the spring semester. In each case, the professor had no prior instructional experience with these classes.

Total enrollment for ECE-360 (traditional format) was 44 students across two sections. This class introduced a broad range of mathematical concepts and theory with topics including differential and difference equations, the Laplace and Z transforms, and the Fourier series and Fourier transform. The class met for three 50-minute lectures per week with a typical meeting consisting of the professor introducing new material to the class, working through examples, and answering questions as they arose.

Total enrollment for ECE-322 (flipped format) was 50 students across two sections. This class introduced students to embedded microcontrollers and covered topics that include assembly and C language programming, microcontroller architecture, and peripherals (timers, serial communication, analog-to-digital converters, and LCD drivers).The class met for five, 50-minute lectures every two weeks and included a 3-hour lab meeting every other week. As a flipped class, during lecture/instruction time the professor would review content from a previously assigned video or briefly introduce a new topic at the start of class. For the balance of the meeting, the professor would assign the next problem spend the majority of instructing time providing hands-on help to the students as they worked through the assignment at their own pace. The labs were structured similarly, but with more time devoted to solving a larger task.

To assess success of the first year faculty member, student performance on the final exam and student self-assessments for a first year, tenure track professor (TT) are compared with tenured professor (TP) who has multiple years of experience teaching both the traditional and flipped format class. Additionally, we compare final exam grade distributions between TT's traditional format and flipped format class to look for any effect in moving from the traditional format to the flipped format. Lastly, interviews with the faculty member were conducted to look for benefits to the faculty member that teaching in a flipped format may offer. TT's technical background includes analog RF circuit design, wireless communication and low-power embedded systems. Considering the various topics of ECE-360 and ECE-322, TT has comparable expertise-levels in the subject areas of both classes. TT's prior, relevant pedagogical experience was working as a lab Teaching Assistant for a microcontroller course at the start of TT's graduate degree program.

Results

Student performance on final exams from the traditional format class is compared between the first year, tenure-track professor (TT) and a tenured professor (TP) having multiple years of experience teaching both courses. The professors' final exams for the traditional format class were nearly identical, with only small differences in questions. Both examinations assessed student mastery using short response questions and application of mathematical concepts through the solution of various problems.

Each professor independently evaluated student performance using four categories from the Department's ABET assessment: Exceeded Expectations, Meets Expectations, Progressing

Towards Expectations, or Unsatisfactory. Evaluated student performance is shown in Figure 2. Assigning "Exceeds expectations" a value of 4 and "Unsatisfactory" a value of 1 allows calculation of a numeric mean. For the traditional format class, TP had a mean of 3.14 / 4.00 and TT lagged behind with a mean of 2.91 / 4.00 for the final exam student performance. While means were similar, TT had almost twice as many students in the "Progressing" category compared to TP.

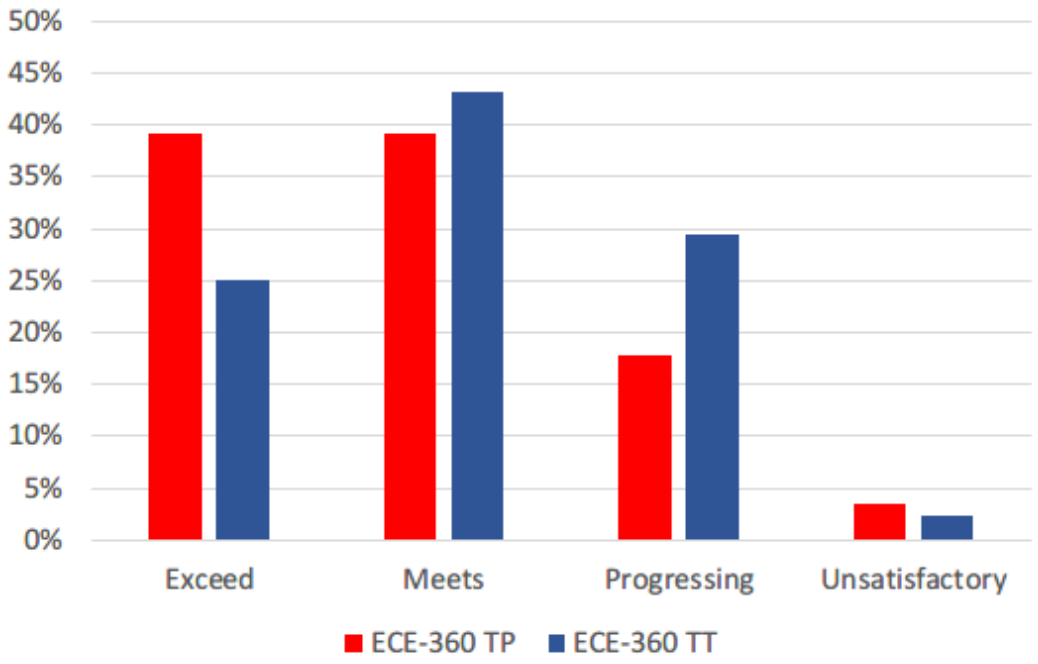

Figure 2. ECE-360 (traditional format) Final Exam Comparison

Next, student self-assessment surveys for the traditional format courses were compared. Students were asked to assess their own understanding of the course material using a 5-point Likert scale. The seven questions are shown in Table 1 with response of 5 indicating "Yes, Definitely" and a response of 1 indicating "No, not at all."

Table 1. ECE-360 Student Self-Assessment Questions

A1	Can you perform graphical convolution in the time and frequency domain?
A2	Can you calculate the output of a discrete or continuous system?
A3	Can you relate a difference or differential equation to its transfer function?
A4	Can you relate pole locations to time-domain response in continuous and discrete-time systems?
A5	Can you determine the stability of continuous-time and discrete-time transfer functions?

A6	Can you compute the frequency response of continuous-time and discrete-time transfer functions?
A7	Can you explain the sampling theorem, Nyquist frequency, and how to identify alias frequencies?

The student survey results for the traditional format classes are shown in Figure 3. For each question, students reported lower confidence in their abilities for TT's course. Overall mean scores for the seven questions were 4.74/5.00 for TP and 3.87/5.00 for TT.

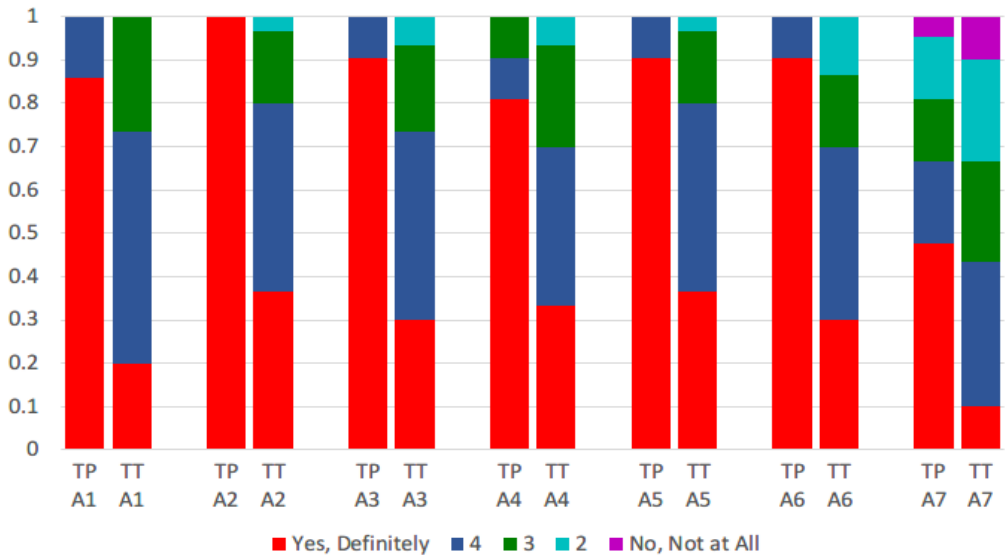

Figure 3. ECE-360 (traditional format) Student Self-Assessment Comparison.

Student performance on the final exams for the flipped format were next compared. As part of each final exam, students were asked to design a system that performs four simultaneous tasks using digital inputs, digital outputs, timers, a serial communication port, and the analog-to-digital converter. Similar to the previous results from the traditional format final exams, student performance was evaluated using four categories ranging from "Exceeds Expectations" (numeric value of 4) to "Unsatisfactory" (numeric value of 1) as shown in Figure 4. The mean of final examination assessment was 3.41/4.00 for TP and 3.32/4.00 for TT.

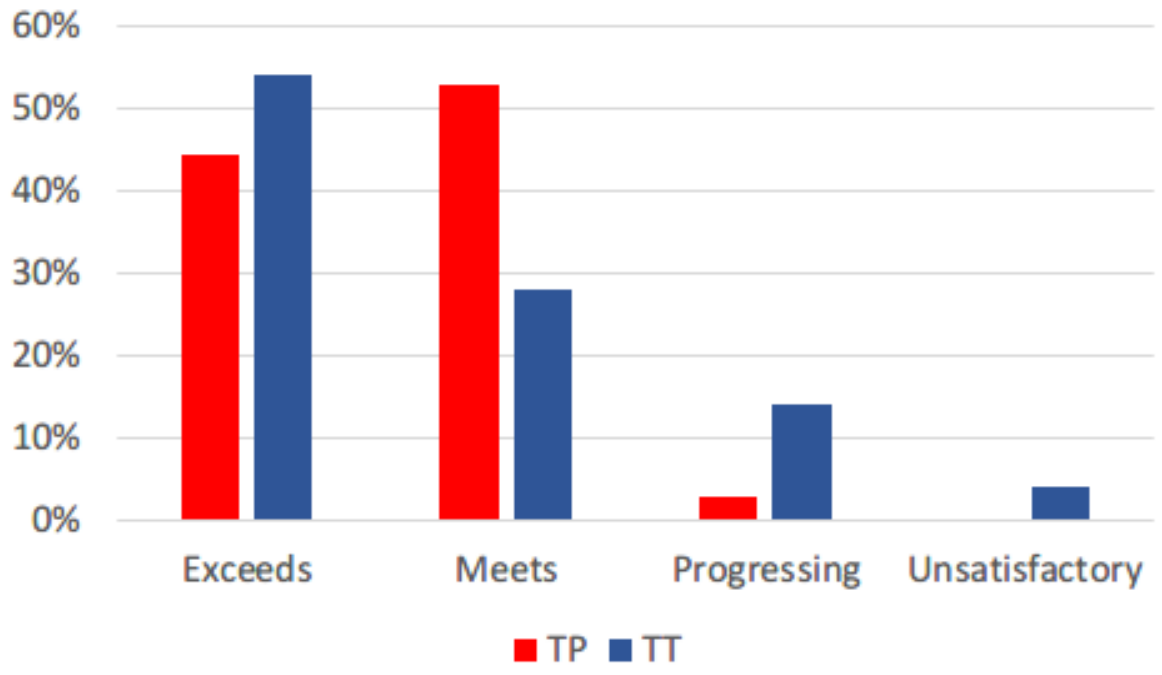

Figure 4. ECE-322 (flipped format) Final Exam Comparison

Next, the student self-assessment surveys for the flipped format classes were compared. Students were asked to respond to the five questions shown in Table 2 again using a 5-point Likert scale, where 5 represented "Yes, Definitely" and 1 represented "No, Not at All."

Table 2 ECE-322 Student Self-Assessment Questions

B1	Can you write and debug programs in C programming language?
B2	Can you create an interrupt driven embedded system?
B3	Can you use timer peripherals in an embedded system?
B4	Can you use a serial port peripheral in an embedded system?
B5	Can you use an analog-to-digital peripheral in an embedded system?

Responses to the flipped format student self-assessment surveys are summarized in Figure 5. Overall mean scores were 4.79/5.00 for TP and 4.91/5.00 for TT.

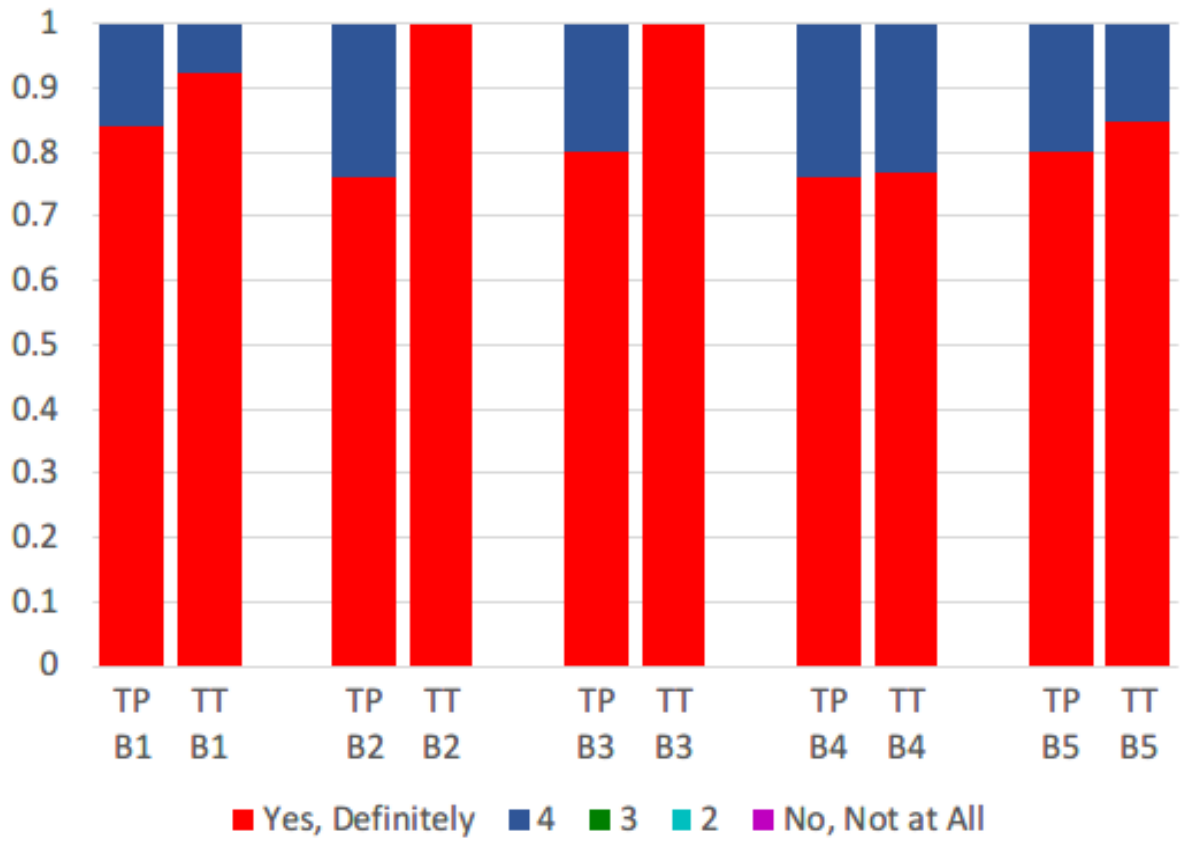

Figure 5. ECE-322 (flipped format) Student Self-Assessment Comparison

To directly assess the the first year faculty member's teaching performance between a traditional format and a flipped format, final examination scores exclusively from TT's ECE-360 (traditional format) and ECE-322 (flipped format) were compared. As shown in Figure 6, student grade distribution for the traditional format appears as a flat (uniform) distribution between 60% and 95% with a mean of 78/100. On the other hand, student grade distribution for the flipped format shows a truncated normal distribution with a higher mean of 88/100.

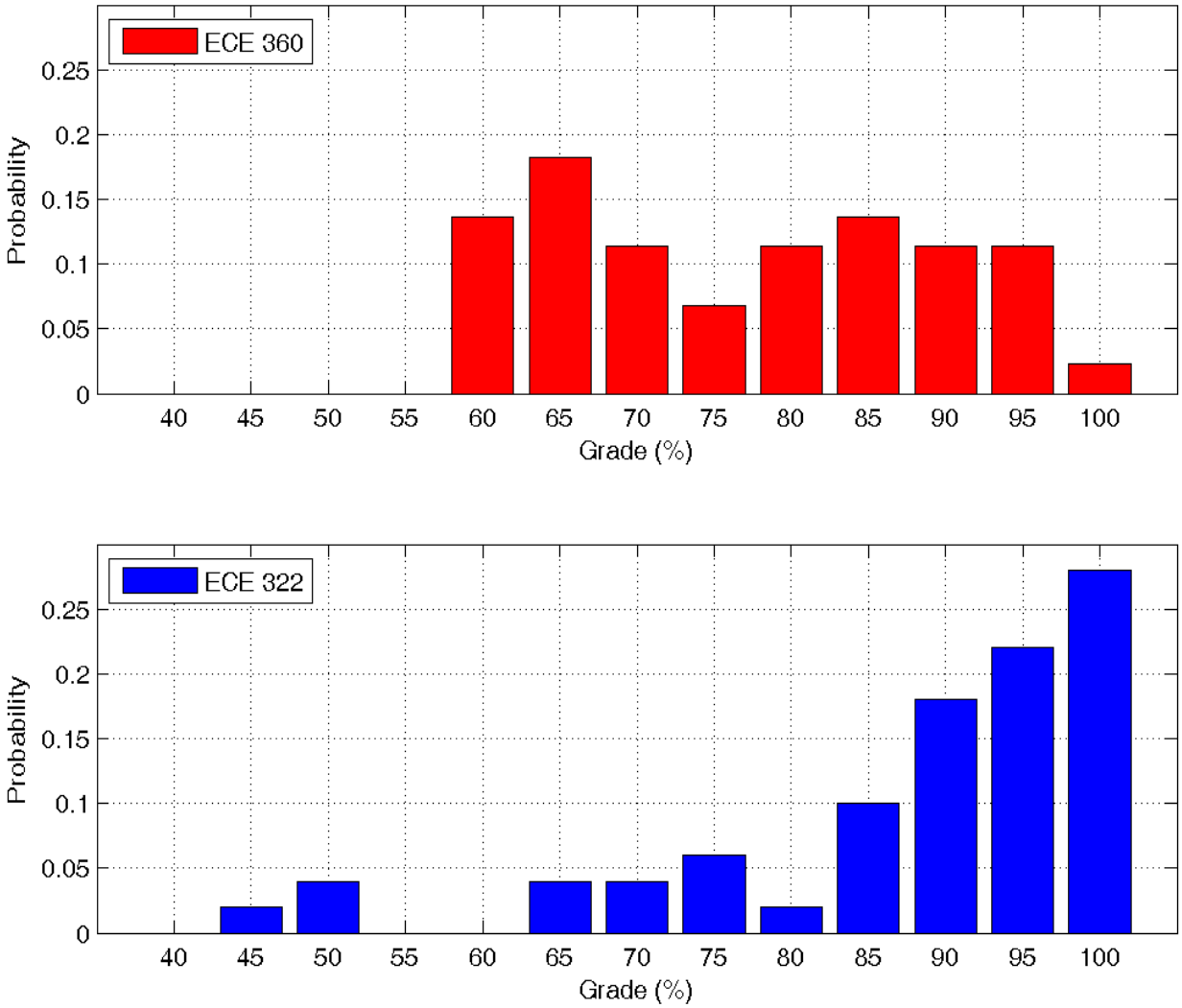

Figure 6. Student Grade Distributions for TT's ECE-360 (traditional format) and ECE-322 flipped format) Classes

Analysis

Comparing student performance on the final exams from TP's and TT's traditional format class (Figure 2), show TP's outcomes form a truncated normal distribution whereas TT's outcomes present a normal distribution with accompanying lower mean. Overall, the number of students found meeting or exceeding expectations was within 10% for Prof. TP (78%) and Prof. TT (70%). While a similar percentage of students were grouped into the "Meets expectations" category, TP had more students exceeding expectations and TT had more students progressing towards expectations.

Looking at Figure 3, which compares self-assessment survey results from TP's and TT's traditional format class, students had greater confidence in their abilities to meet the first six objectives for TP than for TT. For these objectives, average student response was 4.88 / 5.00 for

TP and 4.00/5.00 for TT. Student responses the first year professor had a lower mean and larger standard deviation. It is worth noting that either due to course coverage or the timing of the self-assessment survey, objective A7 has historically received low scores on the Likert scale, and this was no different for TT in this course.

Student performance on the final examination for the flipped format class in Figure 4 shows consistent distribution and shape compared to their traditional format distribution for TP's classes. As TP has taught each course multiple times, this establishes a comparison base between the traditional and flipped classes for the first year professor. In other words, we should expect TT's student performance distribution to be consistent between the traditional format and flipped format if the flipped classroom were to have no effect. Instead, we find overall improvement. The mean of the distribution for TT's flipped format increased compared to the traditional lecture format. More interesting, and in contrast to the final examination results from the traditional lecture format shown Figure 2, TT's performance distribution is now more aligned with that of TP as shown in Figure 4.

Student self-assessment surveys for the flipped format show a similar effect. Survey responses for TP's classes were again consistent with students reporting strong confidence in their abilities. For the first year professor, student self-assessment results show a marked improvement in student confidence compared to the traditional format class and the self-assessment results for the flipped class are more aligned with those from TP (Figure 5).

In the direct comparison in Figure 6, there is a clear shift in student performance on the final exams of the traditional format and the flipped format classes. The grade distribution moves from a flat distribution to a truncated normal distribution with a higher mean.

By all metrics available to us, the first year faculty was measurably more successful in teaching with a flipped format class — even with no prior flipped classroom experience. The data show both a teaching improvement for a first year faculty member and also shows student performance more closely resembling a TP who has taught each course multiple times. However, this is only part of the benefit realized by the first year faculty. We now examine the benefits to the faculty member in teaching with a flipped format class.

Preparation time for the new faculty member was greatly reduced for the flipped format class. Instead of carefully reviewing and practicing lecture material, the professor only needed to invest time in reviewing concepts and preparing to answer questions.

Second, the preparation time for the flipped class was itself less stressful. The flipped format and bundle of prepared handouts provided a "safety net" for the first year faculty member. During extremely busy times in the semester, simply giving students a handout and helping them work through it provided many impactful teaching opportunities. The TT faculty member reported that "even just knowing that the videos and handouts existed, made preparation time less stressful as a successful lesson was always just a handout away if needed."

Third, a marked improvement in both student performance and student evaluations was noted. While this is a useful measure for the course effectiveness, good and positive student evaluations

are also themselves a benefit to the faculty member. As more importance is placed on student evaluations, receiving positive feedback can be beneficial during annual reviews and future promotion and tenure decisions.

The sample feedback below shows that students themselves were more agreeable to the flipped format. In the traditional lecture class, students identified difficulties in keeping up with notes and desiring more time for asking questions. Students sought more in-class examples, and specifically requested examples more closely related to the homework. In contrast, students in the flipped class greatly enjoyed solving problems in-class and welcomed the opportunities to ask immediate questions. In fact one student even identified "*More* in-class time to work on [homework], so we could ask professor if [we] needed clarification" as a future improvement for the course! In general, students in the flipped classroom were more positive about both the first year faculty member *and* the course content itself.

Below are sample quotes taken from the end of course evaluations in TT's ECE-360 (traditional format) and ECE-322 (flipped format) classes (emphasis added).

ECE-360 (traditional format)

- "[TT] needs to slow down in lecture, [I] **cannot always get notes down in class**"
- "**I had a little trouble getting help outside of class**, but managed to ask before/after class for quick questions."
- "**Doing more examples** on the board and less straight off the power point would be helpful."
- "... if you are an auditory or visual learner you can't listen or watch the slides but rather cram as much stuff on a tiny slide as you can to try to remember. ...[please] do extra examples outside to be able to make people still write things down"
- "The **homework should parallel what we are learning in class better.**"
- "**More in class problems** that are similar to the homework would definitely help."

ECE-322 (flipped format)

- "[The most beneficial part of the course was] **programming during class** or examples that [TT] gave."
- "Being able to **work on assignments and start them in class** after a lecture was very helpful so **I could start asking questions**."
- "... I can see myself pursuing a field in embedded design because of this course. This is hands-down my favorite course this semester. **ECE-322 makes me excited for the higher level classes** because I actually get to learn the more practical, valuable topics ..."
- "Actually **working on code in class** was beneficial"
- "Great course! Can't wait until Microcontrollers 2!"
- "**I really enjoyed this class.** [TT] really knows his stuff and is a cool [person]"

In looking through student responses, students noted frustration in the inability to ask questions and receive quick feedback for the traditional format. Students felt the professor was willing to help, but sought more in-class examples and time for questions.

Many of these issues were resolved in the flipped format. Students welcomed the ability to work on assignments during class time, and enjoyed the ability to receive instant feedback. Not only did students mention enjoying the class, but several students noted excitement about the course material and future career opportunities. Additionally, feedback directly concerning the professor was overall positive.

Future Work

The assessment presented in this paper suggests that some difficulties related to onboarding new faculty can be alleviated through a flipped classroom approach. This result is seemingly counterintuitive, especially given that the first-year faculty member had no prior exposure to flipped classroom model. Below we suggest a few possible explanations that could explain our results.

In the faculty member's reflection of the flipped classroom experience, it was noted that this pedagogical model more resembled that of a lab similar to one where a first year faculty member has just emerged from a multi-year research project. In many research labs it is common for senior students to mentor and train the junior lab members. In that sense, working with smaller groups during instruction time did not seem foreign to the faculty member and put both the faculty and students more at ease.

The sequence of the traditional class followed by the flipped class could have impacted the results. In our assessment, the TT faculty member taught the flipped class in their second semester. This means that the faculty member had a full semester to become accustomed to the new surroundings and institutional norms. In other words, better instruction could be a result of being better acquainted with a new position.

Another possibility is the faculty member having more personal interest in the subject of microcontrollers over that of signals and systems. This is a difficult variable to isolate or control for as instructors will always have various personal preferences. At Valparaiso University, teaching assignments were distributed by matching faculty with their self-reported teaching interests. In the summer prior to TT joining the faculty, TT filled out such a survey and self-reported similar interests in both course subject materials.

Lastly, even something as subtle as the time of day could have influenced the class performance. The traditional class was taught by TT in the first two time slots of the day (8:00 AM and 9:00 AM) whereas the flipped class was taught later (11:30 AM and 12:30 PM). The later time of day could have impacted the students' willingness to learn or allowed TT more time to prepare lecture material during the morning instead of the night prior to lecture.

All this suggests that more research in this subject is needed. We have shown that a first year faculty member can be more successful with a flipped class. However, there are many possible reasons that could aid in explaining why this is the case. We have suggested the above items as a starting point for future researchers investigating this subject.

Conclusion

In this paper, we asked if a first year faculty member can be more successful in teaching with a flipped format classroom. By all measurable metric available to us, we find that not only can a first year faculty member be more successful in teaching with this format, but there are also additional positive benefits for the faculty member. We found that with a flipped format presentation, both evaluated student performance and student self-assessment surveys were similarly distributed between a tenured professor with multiple years experience teaching the course and a first year faculty member. This was in contrast to a traditional lecture format, where the first year faculty member showed poorer effectiveness in student performance and self-assessment reporting.

In addition to achieving improved measurable benefits to the student, we also found the flipped format offered benefits to the faculty member. This included both less amount of needed preparation time and less stressful preparation. Additionally, in student self assessment surveys, students enjoyed the flipped format and gave the course high rankings.

Further research is needed to control for factors such as course material and student populations. However, our data suggests that a first year faculty member can benefit in several ways and be overall more successful in teaching with a flipped format class.

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