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Cover Page Footnote

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Flipping the Feedback: Formative Assessment in a Flipped Freshman Circuits Class

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This paper describes the application of formative assessment methods in a flipped freshman engineering circuits course. This student-centered approach provided value for the instructor seeking to improve the learning environment and content in real-time, and for the students who actively participated in the process of course improvement. Three types of assessment were used in this course: online formative course feedback every three weeks; weekly 'muddiest point' content feedback; and midterm exam scores. Data were assessed using a mixed-methods approach. The formative feedback from this course provided information on how students perceived the flipped classroom and how those perceptions changed across the semester. This approach provided a low-effort strategy for incorporating the student voice for teaching and learning improvement. Although the intended assessment outcome was real-time improvement of the course, an unintended outcome of incorporating student voices and reflection during the course process was realized. Student acceptance of the flipped class increased as the semester progressed, and they placed high value on in-class active learning, the ability to re-visit the online lectures, and having a professor who valued their feedback and suggestions for course improvement. The majority of students also faced time management challenges that extended beyond this specific class.

Introduction

As teaching pedagogy evolves, and faculty move from passive to more active teaching, we must consider aligning new assessment strategies to these new teaching methods. Active teaching and learning contexts that are more student-centered require a more continuous, student-centered assessment strategy. Shifting the paradigm from a summative approach of measuring *products* at the end of a course, to a more formative and continuous evaluation of the *process* of learning, has emerged as a credible and effective approach for measuring successful student learning (Angelo & Cross, 2012; Huba & Freed, 2000). Black et al. (2004) claim, "Assessment becomes formative assessment when the evidence is actually used to adapt the teaching work to meet student needs" (p. 10). New student-centered teaching strategies in the classroom, such as flipped teaching, require a more student-centered assessment approach to uncover student perceptions and needs. In this paper, we explore how a formative assessment strategy can be used to assess and adjust the flipped classroom experiences in real time while assessing student learning and skills development. We also explore how this strategy engaged the students through personal reflections of their own learning practices (Svinicki, 2019). This integrated assessment practice provides a broad snapshot of the student learning experience through student eyes, in a flipped classroom throughout the semester and insight for improving the active learning instructional process. This method can be across disciplines and course levels.

In this paper we present a case study in which we monitor how students in an introductory engineering circuits class experienced learning in a flipped learning environment. The course was taught by an experienced professor who had been flipping graduate and higher level undergraduate courses, but had not taught first-year engineering students. Using backward design, she redesigned the course in a flipped format with pre-class video lectures and active learning and problem solving activities in the face-to-face (F2F) classroom. A formative assessment plan was designed and implemented to gather data at regular intervals across the semester to help improve the course. The student feedback was often deeper and more personally insightful than anticipated, and we observed that this assessment strategy could be used to improve student learning engagement through self-reflection, as well as, incorporate the student voice into the learning and assessment process (Healey et al., 2010; Jensen & Bennett, 2016). While other papers have addressed the learning gains from active learning and the flipped class (Baepler et al., 2014; Mason et al., 2013; Suskie 2018) including one on a freshman circuits course (Yelamarthi & Drake, 2015), we will focus on the student learning experience rather than the grades themselves. The student voice comes out clearly in these assessments, as we watch their progression through the semester.

Context and Review of Literature

While most flipped classroom studies focus on comparing the learning outcomes from traditional lecture delivery to the flipped format (Mason et al., 2013; Suskie 2018), we focus on the student learning experience in a flipped context throughout the semester as it unfolded. The flipped classroom is initially new to most students, but most adjust quickly to the new format and like it by the time the end of the class (Bishop & Verleger, 2013; Wanner & Palmer, 2015). We will discuss how students engage and adjust to the flipped classroom over a semester timeframe.

The Flipped Classroom and Active Learning

Blended or hybrid learning, more of a pedagogical approach than a type of learning, combines the instructional advantages of the traditional F2F classroom with the flexibility of an online learning environment (Diep et al., 2017; Furse, 2011). The flipped classroom, a specific type of blended teaching method, moves didactic lectures outside of the classroom so more active learning can take place in the classroom (Sams & Bergmann, 2013). It has been implemented in many disciplines, levels, and types of courses (Bishop & Verleger, 2013). The success of the flipped classroom is often attributed to the active learning it enables when the lectures are moved out of the classroom context (Jensen et al., 2015; Lovvorn & Timmerman, 2019). Students have more contact time with the professor, more time to interact with and learn from peers, and more time to ask questions and clarify concepts (Freeman et al., 2014; Kuh et al., 2008,) which can lead to better academic achievement, persistence, and attitudes (Alonso et al., 2011; Prince, 2004; Springer et al., 1999; Yelamarthi & Drake, 2015). In the flipped classroom, faculty can observe first-hand where students struggle, identify learning bottlenecks, and incorporate just-in-time teaching strategies as students apply course concepts (Furse et al., 2018; Silberman, 1996). In a traditional classroom, students do the work of learning outside of class as they struggle alone doing homework and they can become frustrated without the just-in-time feedback and learning community interaction.

Formative Assessment Strategies

Formative assessment can be used to adjust and improve teaching and learning in real time (Black & Wiliam, 1998; Chen et al., 2018). Chickering and Gamson (1989) maintain that students need frequent opportunities to receive feedback about how they are learning and about ways they might improve. This is what we sought in our assessment strategy. Nicol and Macfarlane-Dick (2005) claim that:

> "good feedback practice: facilitates the development of self-assessment (reflection) in learning; encourages teacher and peer dialogue around learning; helps clarify what good performance is (goals, criteria, expected standards); provides opportunities to close the gap between current and desired performance; delivers high quality information to students about their learning; encourages positive motivational beliefs and self-esteem; and provides information to teachers that can be used to help shape the teaching" (p. 4).

Formative assessment becomes a starting point for better learning and instruction (Tomlinson, 2007). Through active engagement with peers in the classroom, students have opportunities to not only reflect on their own learning, but also learn from others (Crouch & Mazur, 2001; Lovvorn & Timmerman, 2019). By reflecting on their learning experience, students can develop more self-directed approaches that will help them personalize instruction, incorporate learning-how-to-learn strategies (Crouch & Mazur, 2001), and take a more proactive role in their learning. Self-reflection and taking a proactive role in learning may result in improved learning and more effective learners (Ross, 2009; Zimmerman & Schunk, 2001), something we observed in the case study described here.

Formative feedback and continuous evaluation of the student learning experience can help faculty assess learning in real time, make adjustments, and customize student learning experiences (Rodgers et al., 2013). One of the key concerns about formative assessment has been the amount of time required from both the students and faculty (Healey, et al., 2010; Poza-Lujan, et al., 2016), so the strategies employed in our study were designed to be quick and easy.

Student Learning Engagement and Student Voice

Incorporating 'student voice', which formative assessment facilitates, is an emerging strategy that encourages faculty-student partnerships to improve the teaching and learning process, enhance motivation and commitment for deeper learning (Bryson & Hand, 2007; Zhang, et al., 2016), increase metacognitive awareness about the learning process, and improve the teaching and learning experience for both faculty and students (Cook-Sather et al., 2014). Incorporating the student voice in our case study was critical, for both improving the class, and also for understanding the student experience as they encountered the flipped class for generally the first time.

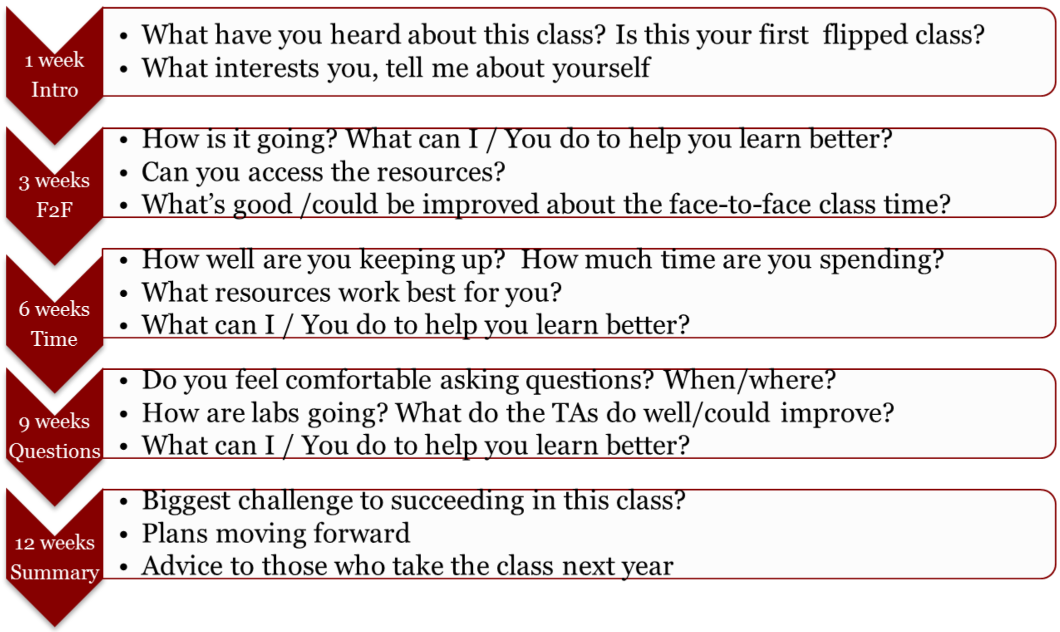
Methods

The formative assessment reported in this case study is taken from the Introduction to Electrical and Computer Engineering (ECE) course, which is a 4-credit course at the University of Utah. The students in this course make up the study population for this paper. In spring 2014 when this data was collected, 118 students registered for the course, 15 of whom were repeating the class. Since this time, formative assessment data continue to be collected in this course. The course is required for first-year ECE students, who make up 72% of the class. The rest of the enrollment comes from other engineering or STEM disciplines, where it is an elective course. The course is a typical first-circuits course covering basic circuits and their applications. It is taught three days a week for 50-minutes in a large stadium-style classroom. The course also has a 3-hour weekly hands-on lab taught in smaller sections by teaching assistants.

Dr. Furse, one of the authors of this paper, was experienced with flipped teaching, but had not previously taught freshmen. She flipped the course by recording video lectures on a tablet PC and posting them on YouTube™. Each day's lecture was approximately 15-20 minutes of video, broken into 3-5 min segments. Students were expected to watch the videos before coming to class, but no specific incentive was given to do so. From online analytics, approximately 80% of students watched at least part of the lecture before class. The F2F class started with a short student-driven recap of the lecture (about 5 min), and then proceeded to peer-to-peer problem solving sessions (3-5 problems, 3-4 min each), with ad hoc, just-in-time problem solving support (mini-lectures) from the professor), finishing with a discussion (about 10 min) of a real-world application.

The professor chose a formative assessment strategy to help improve the course in real time, rather than waiting for the traditional summative end-of-semester student evaluations. Every 3 weeks, voluntary feedback on specific aspects of the course (e.g. could they access the online materials, did they feel comfortable asking questions, how were the TAs doing in the labs, etc.) was requested in a short online survey for a small amount of extra credit. Each assessment also included, "What can I / you do to help you learn better?" At the end of each week, students were asked for the most confusing 'muddiest' point that week to identify topics students were struggling with (Angelo & Cross, 2012). An outline of the assessment questions and schedule is given in Figure 1.

Figure 1. Formative Assessment Overview. In Addition, Weekly 'Muddiest Points' Were Collected to Identify Challenges Students Were Having with the Technical Work.



The professor used the feedback to continually adjust and improve the course in real time, thus truly meeting the definition of formative assessment given by (Black & Wiliam, 1998). Towards the end of the semester she observed that simply asking these key questions caused many students to be self-reflective, and change their learning behavior as a result. We then re-evaluated the feedback using constant comparison qualitative methods (Strauss & Corbin, 1998) to learn more about the student experience. The qualitative feedback was coded and recoded, with themes emerging from the coding categories. These themes were then used to triangulate the quantitative data. This data is reported in the following results section.

Results

The formative assessment strategy that was designed to uncover a rich description about the student experience across the semester is outlined below.

1. Weekly 'Muddiest Point' Data

Each week students were given an extra credit online assignment, "What is the most confusing point this week? Try to answer it." The number of responses varied from week to week. The majority of muddiest points were predictably the most difficult or complex topics of the week, but some were less obvious challenges. These are reported in detail in (Baepler et al., 2014). In a few cases, they pointed the professor to some bottleneck issues (Middendorf & Pace, 2004) that impeded student learning. The professor corrected misconceptions for individual students and shared an overview of the muddiest points with the class. For bottleneck issues, she provided supplemental material, and eventually adapted the textbook. In many cases, students expressed emotion such as curiosity, excitement, uncertainty, lack of confidence, anxiety, etc. along with the technical questions, and in these instances the professor tried to add a personal note of encouragement via the online LMS. In other cases, these also enabled the professor to reach out to the student personally.

2. Formative Learning Experience Feedback (Every Three Weeks)

Week 1: Getting to Know the Students

In the first week of class, students submitted a short survey on why they chose engineering, what interested them about the field, what they had heard about the class, and something non-technical about themselves. The professor used these responses to choose popular example applications (e.g. electronic music, computers and gaming, optics, biomedical, space exploration), remember student names, and generally get to know her class and be responsive to their interests. A few students voluntarily shared specific learning disabilities including ADHD, autism, Turrets syndrome, depression, and dyslexia. The professor reached out to the Center for Disability Services for advice on how to improve teaching for these students.

Students were also encouraged to take an optional questionnaire (for a small amount of extra credit) to assess their learning styles (Soloman & Felder, 2005), read a short description of their learning style, and write a short reflection on what techniques they could use to improve their learning. Of the 118 students enrolled in the class, 70 (58%) completed this questionnaire and reflection.

Week 3: Initial Experience with the Flipped Class

In the third week of class, students evaluated their experience with the flipped classroom, and 52% responded. For 73% of the respondents this was their first flipped class. Fifty-six percent of the students liked the flipped class at this point, 9% did not, and 35% were unsure. Students liked that the lecture videos were posted online, as this allowed them to watch them repeatedly. The videos were especially important to English as second language (ESL) students. The students also appreciated the ample resources (math links, supplemental videos, office hours, TA info, etc.). Some highlighted positive experiences with group problem solving, the in-class examples and the professor's genuine interest in the students. Students asked for a concept review or informal lecture at the beginning of class to make sure they understood the video lecture, which the professor implemented. Others suggested that they needed incentives to come to class and felt the class moved too fast. The professor acknowledged these concerns, but encouraged the students to take personal responsibility to come to class, and to put in additional time as needed. In several cases, this inquiry caused the students to reach out to the professor in person, and positive discussions occurred as a result.

Getting the students to ask questions remained a concern for the professor, who observed freshmen seemed more hesitant to ask questions than more experienced students in classes she had taught previously. She was trying to help them gain that confidence using pair-share and other methods. Still, only 43% indicated they were comfortable asking questions in class, 19% preferred asking their questions outside of class, and 36% said they were uncomfortable asking questions at all. Common reasons were language issues, shyness, not confident about the material, and large class size (all of which were also mentioned as contributing factors for preferring to ask fist ask peers rather than instructor/TA (Thompson, 2008)). While more experienced students are likely to continue to feel these same feelings (and therefore reticence to ask questions) to some extent, they are also likely to gain in confidence and feel less shy as they become more familiar with peers they have taken numerous classes with, and class sizes generally are smaller for more advanced students. Most students also self-reported that they were not putting in the time they should be preparing for class, which highlighted the time management issues that became a major theme in learning challenges.

Week 6: Midterm and In-Class Activities

After the first midterm, students were asked for feedback again. 45% responded. The majority (about 75%) said the exam accurately portrayed what they knew, were able to find their own mistakes and felt well prepared for the exam. The majority of those who performed poorly reflected that it was due to lack of preparation and/or lack of time commitment. Ten percent indicated they disliked the flipped class and wanted to go back to the more familiar lecture format. Some students said the class was going too fast. Others wanted more examples, and some said the examples should be simpler, individual concepts, rather than using several concepts linked together. Many students were appreciative of the efforts that the professor was making to include their feedback in the class.

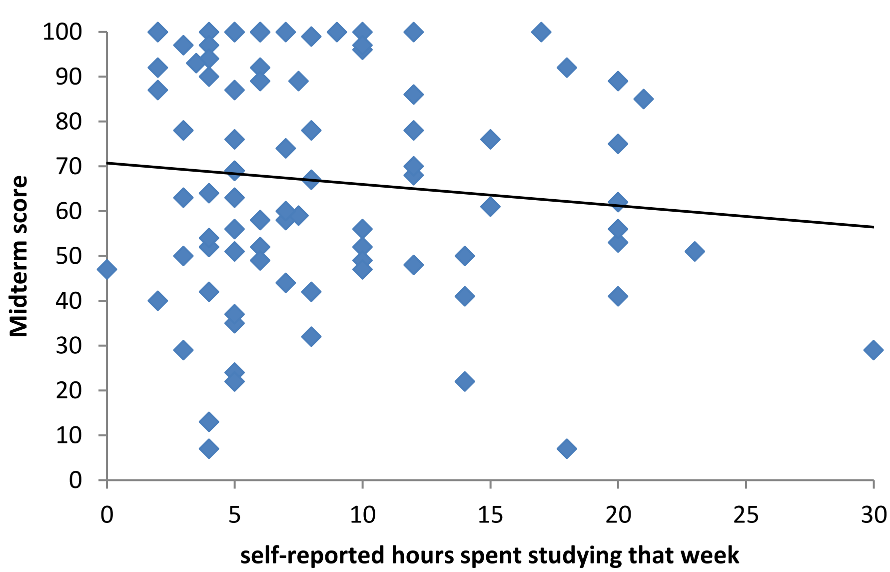
The professor shared the overall responses with the class, explained that linking concepts was important in the class, and provided additional online examples. Many students also said that they needed to manage their time better (time management turned out to be a major theme throughout the semester) and put in more effort to learn the material (watch videos, take notes on the videos, attend class, and ask questions). According to student involvement theory (Astin, 1984), the extent to which students can achieve particular developmental goals is a direct function of the time and effort they devote to activities designed to produce these gains. We explored this theory by evaluating the midterm score vs. the self-reported time spent studying for the exam, shown in Figure 2. There was tremendous variance in the data. Many students who spent little time studying for the exam did very well (perhaps being well-prepared in advance), and some who spent a great deal of time did poorly. Time, alone, was clearly not a strong predictor of how well a student would do on this exam, as also noted in Baepler et al. (2014). There are a variety of reasons for this including that different students require different amounts of time to learn material (due to natural differences in learning styles and methods, background, etc.). Some students may have kept up with the material continually throughout the semester, and others will be cramming at the end, etc. As we found from student comments, time management is a serious issue for these students, which would also lead to uneven preparation time. Thus, the measure of time spent in the week before the exam is a poor proxy for learning, as we see in Fig. 2. Also, it is important to realize that students self-reported only an estimate of their time spent, which severely limits the accuracy of this data. Future studies may use other metrics, such as more accurate measures of time, totality of time spent over the entire learning and preparation time for the exam (typically over multiple weeks), and interactions measured via the learning management system.

Week 9: Engagement, Asking Questions, Use of Resources

After the second midterm, students were asked about their level of engagement in the class, specifically collaborative learning, effective teaching practices, student-faculty interactions and a supportive environment. Over 40% of the students responded. Some feedback indicated the importance of being able to share their experience with the professor. We compared students with scores above/below 75%. Table 1 explores where students were asking questions.

One observation from Table 1 is that lower achieving students reported that they were more likely to ask questions either in class (raising their hand) or to another student. Informally, the instructor confirms this general observation. One likely reason for this is that higher achieving students were more likely to learn and understand the material quickly and easily for a variety of reasons (individual learning style, background preparation, time spent on pre-lecture preparation, video watching, book reading, preparing notes), and therefore were more likely to be answering than asking questions during in-class group work or outside-of-class study groups. Another possible reason is that if a student is uncertain about something, they are more likely to ask a peer first rather than approach the instructor or TA, but this effect is seen regardless

Figure 2. Time Spent Studying for the Exam (Self-reported) vs. Midterm Score



of the higher/lower achievement of the students. This preference for asking a peer first was also seen in Thompson, 2008. In future surveys, it would be interesting to ask if asking questions to peers was inside of class or outside, indicating the interaction with the peer-based active learning used in this class. It is encouraging that the majority of students found some method by which they could ask their questions, however a very important caution is that the majority of students did not report raising their hand to ask a question in class, or formally reach out to the instructor or TA in office hours or emails. This points to the importance of having a variety of ways for students to ask questions, including peer-based methods, and the importance of being sure that all students can access peer-based methods. For instance, relying on individual study groups arranged by the students, which are a traditional mainstay in engineering study patterns, may limit inclusion of working students, minority students or women (Austin & Creamer, 2011; Elliott & Reynolds, 2014). Given the importance of peer-based questioning, formal methods that include all students should be planned into a course

Table 1. Asking Questions vs. Scores

How have you asked questions?	Higher Scores (>75%) N=26	Lower Scores (<75%) N=21
To another student in class	46%	71%
Raising hand in class	27%	43%
Online discussion board	19%	19%
By email to instructor	15%	19%
To instructor face-to-face	31%	29%
In lab	73%	76%
In TA tutoring sessions	27%	15%
Never asked a question	27%	0%

Table 2. Resource Use vs. Scores

Which of these resources do you find valuable to help you learn?	Higher Scores (>75%) N=26	Lower Scores (<75%) N=21
Video lectures	85%	76%
In class examples	85%	62%
In class problem solving	46%	48%
Textbook	58%	62%
Online resources	42%	24%
Labs	65%	43%
TA	35%	33%
Instructor's office hours	27%	19%

Table 2 shows how students used the various learning resources. The prioritization of the video usage is consistent with what others have observed in flipped courses (Zhang et al., 2016), however the students were utilizing the full range of resources provided, but not necessarily in the same order. For example, many described that they watched the videos, came to class, and used the book only if needed. A few watched the videos, read the book, and then came to class. Most students utilized examples from either videos, in class or in the book extensively in their learning.

In the two groups of students there were significant differences (effect size of 0.3 or greater) in their use of the textbook (higher performing students used it more) and their experiences with other students in the class. Lower performing students said the class encouraged more contact amongst students. The lower performing students preferred to ask questions to other students in the class, while 27% of the higher scoring students preferred not to ask questions and to figure things out on their own, something not reported by any of the students in the lower scoring group. Both students felt that the class provided them with the support and resources they needed to succeed. Those in the lower scoring group often commented on their own lack of effort or poor time management skills as the primary contributor to their poor performance. Our university's non-traditional demographic where a majority of our engineering students are working 20-40+ hours a week may impact these issues. Several students contacted the professor individually at this point, discussed their life/school situation, and came up with methods to improve. Future research on ways to teach this specific content as time-efficiently as possible is warranted.

Week 12: Overall Assessment of the Flipped Experience

Students were asked to reflect upon their experiences with the course and provide recommendations for next years' students. The most common themes on what had worked well were in decreasing order of frequency: 1) the flipped classroom and availability of online resources; 2) the labs (hands-on experiences) and their connectedness to class concepts; 3) the quality of the professor and her teaching style; 4) the flexibility to be able to make-up or retake an exam to improve final grade; and 5) posting solutions to the problem sets. The overwhelmingly strongest challenge theme was time management (balancing a job with school, balancing a very full class schedule or working with procrastination and poor study habits). Nearly 60% of the respondents stated this as their biggest challenge. Time management issues were the dominant challenge across all demographics with the exception of the international students, who primarily reported language as their biggest challenge. These students liked the online lectures so that they could slow down the video, or watch it repeated times. Other less frequently reported challenges included an inability to sort out important concepts, and two students reported a lack of interest in the subject matter. Table 3 compares student opinion of the flipped class in weeks 3 and 12.

Table 3. Student Opinion of the Flipped Class

Do you like the flipped class?	Week 3	Week 12
Positive	56%	65%
Unsure or neutral	35%	21%
Negative	9%	14%

Qualitative Comment Analysis

Through the qualitative analysis of 669 open-ended comments provided by students across the course, several major themes emerged. In addition to providing context for the tri-weekly feedback questions, all comments were coded and then categorized together using a constant comparison iterative qualitative process (Strauss & Corbin, 1998). The main themes that emerged were: 1) *flipped learning environment*, 2) *assessment strategies*, 3) *course and lab logistics*, 4) *balancing life and academic activities*, 5) *learning experience needs*, and 6) *classroom climate*. It was no surprise that the largest category of codes was the flipped learning environment, because of the number of times students were asked about this specifically. Students often mentioned the importance of time management, and how it was a lot of work to stay on top of video lectures, in-class active learning, and follow up homework expectations, although the workload was specifically designed to be the same as for a traditional class (trading off homework done in class for lecture watching outside of class). Some students liked this pedagogical approach, for example, "I like flipped classrooms. It allows more time for examples" and "it allows us get our questions answered faster than regular classroom setting". But other students articulated their negative opinions about the flipped approach. Reasons provided included: "I really do not like it because it relies heavily on the student learning everything himself while class is just a review session" and "I still need to adjust a little more to the flipped class room because I am used to learning the material in class and setting aside time for homework. I am struggling a bit with watching lectures before class" Other students were on the fence and did not like the teaching approach but could see a benefit such as "… I can go back to the lectures and watch them again if I don't understand."

Some also commented that flipping was not really a new method, that it is similar to having pre-class readings and being expected to come to class prepared, and that it helped improve their learning. One student discussed how they were anticipating "regular lectures" and this method was really just a way to help students learn on their own,

> To be honest, even though I really like the flipped classroom, I think that the one thing that I wanted personally from this class was regular classroom lectures. Not that this teaching technique doesn't work, just that I feel like we have to go out and learn most of this information on our own, and that's all I've done with electronics my whole life. I was so excited to get a regular classroom lecture experience on this stuff and then all I get is the exact same thing I've had for 15 years.

The classroom climate coding focused mostly on the attentiveness, passion and flexibility of the instructor. Students reported that "the classroom was comfortable" and the "instructor passionate and excited about the topic". One student's comment was representative of the group, "The thing that helps most in learning is the excitement of the professor and the love they have for the subject and for teaching. You … get the rest of the class excited about the subject and learning and discovering what can be done with it all."

Students were appreciative of the professor taking their feedback seriously. The classroom climate, passion of the instructor, and the focus on students were all aligned to the comments about the "quick response to their questions", the flexibility in grading, and how the content "fit incredibly well with the labs that we were doing." All of these aspects of the learning experience were fair and transparent. Students reported having, "the ability to see what is being emphasized in class". The consistent formative and summative assessment structure contributed to students' expectations about the course and how the students could envision their learning unfolding across the course. By the end of the semester, most students either liked or were neutral about the flipped classroom. Either way, most were generous and vocal expressing their academic needs, perhaps because of the openness of the professor to student feedback.

Discussion and Conclusions

The purpose of this study was to explore how students in an introductory engineering circuits class experienced a flipped course environment, and how formative assessment could be used across the course to allow the professor to gain insights into student bottlenecks and learning issues. By encouraging the students to discuss the act of learning in real-time, it set up an opportunity for self-reflection that led, in many cases, to improved student engagement, students taking more responsibility for their own learning (Bryson & Hand, 2007) and increased metacognitive awareness about their own learning experience, also seen in Young & Fry (2008). The continual reflection process also created an opportunity for self-directed learning and embedded student voice and perceptions into ongoing improvement in the teaching and learning experience (Cook-Sather et al., 2014). This formative assessment feedback strategy could be applied to a variety of disciplines.

Although the majority of students preferred the flipped class, it was difficult to evaluate the effects on academic performance. The course was previously taught by different professors in a traditional format, and some of the content was different. In our study, 67% of the students passed the class, and of these 23% received A/A- grades. The overall DFW rate (when students get a D, F, or withdrawal) was 32.7%, with 17% withdrawing officially or unofficially. In later years, the DFW rate approximately halved (17% in 2017), and the A/A- grades increased to 40%. This could be due to refinement of the curriculum and teaching, smaller class size (the class is now about 80, due to teaching it 3x/year rather than twice), or more experience on the part of the professor, but we cannot substantiate any of these reasons. In this study, there was little difference between male (DFW=31%) and female (DFW=33%) pass rates. International students passed at a higher rate (DFW =15%). Caucasians (white) (DFW=21%) and Asians (DFW=17%) were underrepresented in the group that did not pass, whereas Hispanic/Latino, Black and American Indian were over represented (DFW=71%). This is a concern worth addressing in the future. 47% of those who were repeating the class passed.

Student Learning Experience in a Flipped Classroom

The student preference for the flipped class format increased from the beginning (56%) to end of semester (65%). Students particularly liked being able to repeat the video lectures, and ESL students liked how they could re-watch videos, slow the speed, and even close–caption the video lectures in their native language. Students who disliked the flipped classroom wrote that they were "traditional" learners and wanted a traditional learning experience, that this was not the way they were "taught to learn". Some suggested it might have worked better had they been taught this way from the beginning (i.e. primary/secondary school). Other students said it allowed them to slack off and not come to class, assuming they could watch the lectures before an exam without coming to class. Student feedback suggested that active learning was difficult for many to adjust to. Time management challenges were the dominant theme throughout the semester, likely a common theme in most first-year engineering courses (Felder et al., 2002). Many of the students are non-traditional students and were juggling school and work and expressed concern and frustration with managing time consistently as required across a flipped course. In the final course reflection when asked to give advice to students in the next year's class they expressed their lessons learned. Students stated, "I would tell future students to be very diligent about managing their time and plan accordingly. Falling behind is very easy to do and proper planning may help prevent that" and "the biggest challenges that I faced was time management. The flipped class, constant homework, and labs all require the student to be diligent and up to date on many different things."

Students learned from each other, which encouraged positive motivation and increased self-esteem (Ullah & Wilson, 2007). Students could see they were not the only one with questions, and the active learning classroom provided a safe environment for testing knowledge and asking questions (Lynch, 2008), although many students still preferred to ask questions in an individual setting (office hours, TAs, email). The lower scoring students indicated they were more comfortable asking their classmates questions, and many of the higher performing students suggested a preference for working on their own. Increased student engagement was expected to lead to increased retention and academic success, which we did not see initially, but have in subsequent years. This, we think, is most likely due to the instructors identifying and addressing bottleneck issues.

Implications for Teaching Practice

We found that formative assessment done in this way was a relatively easy and effective way to collect meaningful student feedback and engage students in their learning. It was also a good way to incorporate the student voice into the learning and assessment process, and encouraged students to deepen their learning via self-reflection (Healey et al., 2010; Jensen & Bennett, 2016). The professor was able to see in real-time where students struggled, identify learning bottlenecks, and incorporate just-in-time teaching strategies (Novak, 2011; Silberman, 1996,). By focusing on the student experience and soliciting the student voice, the professor continually improved the class, and the students perceived the professor as caring about them, which in turn promoted a more supportive learning community. This also created a context for students to take a more proactive role in their learning (Weimer, 2002).

Recommendations and Future Research

We have shown a simple way to assess and improve the student learning experience in real time. It would be interesting to further study how the reflective questions themselves seem to help the students become more effective learners, and if there is an optimal time or sequence to do so. It would also be interesting to quantify how student behavior (use of specific materials, time spent, question asking behavior, etc.) changed after reflection. Our assessment showed that even in a large class, student-centered teaching and formative feedback strategies provide a significant level of individualization. How to best enable this individualization, from both the student and faculty perspective, remains an intriguing question. The use of formative assessment of the type described in this paper, and in particular the two questions, "What can I/you do to help you learn better?" is a step in the right direction.

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