



Student-centered and Teacher-friendly Formative Assessment in Engineering

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Evidence-Based Practice: Student-Centered and Teacher-Friendly Formative Assessment in Engineering

Abstract

Student-centered teaching employs active learning strategies that engage students in ways that meet their individual learning needs. When adapting from a teaching-centered pedagogy to a student-centered pedagogy, faculty must also make changes to the assessment strategies they use; student-centered teaching requires student-centered assessment. In addition to summative assessment that measures student learning and knowledge through traditional products such as exams, quizzes and papers, formative assessment evaluates the process of learning, and the experience of the individual student. Understanding this student experience can be extremely valuable to both the student and the faculty member, particularly when using a teaching strategy that is new to both.

This paper describes a qualitative action research project to learn about the student course experience and help the faculty improve the course. This project methodology uses a simple and efficient formative approach that incorporates strategic and continuous open-ended survey questions in optional feedback assignments to gauge the student experience across the course. Data were collected in the course learning management system (LMS) for multiple sections in a freshman Introduction to Electrical and Computer Engineering (first circuits) course using a flipped pedagogy across four years and with three different instructors. These assessments focused on identifying challenges to learning, or “Muddiest Points” and student perceptions about classroom strategies and general learning/academic concerns. Simply asking “What can I do to help you learn better? What can you do to learn better?” helped students reflect on their learning behaviors, and in many cases, improved their experience throughout the course. This strategy provided an opportunity for students to take more responsibility for their learning and voice their feedback about the course. The assessments also helped the faculty member improve the course in real time. With this approach, the instructor also identified a number of learning bottlenecks, where a significant number of students were having problems. This very simple formative assessment strategy proved to be a powerful tool for creating a student-centered course. Findings from this study included providing the instructors: (1) a transparent map of the student learning processes; (2) evidence of changing perceptions about the flipped classroom across the course; (3) confirmation of the value of faculty student centered approaches; and (4) the revelation of lessons learned by reflecting students. Recommendations from students will also be discussed. It should be noted that this paper focuses on the student experience in what was generally their first flipped class, and (because they were freshmen) also one of their first college classes.

I. Introduction

Changing student demographics and an emerging assessment and accountability in higher education have resulted in change in the teaching and learning literature about how people learn [5-7]. In 1995, one of the most influential and seminal education papers by Barr and Tagg [8] began a tide of change for moving from the concept of a teaching paradigm where the instructor

is the “sage on the stage,” to a more learner centered approach where the instructor became more of a “guide on the side” during the learning process. This shift from a teacher centered to student centered learning experience also resulted in a move from passive learning to active learning. As students become more active learners [9], it has also become important to reconsider how we assess student learning [10]. Assessing “active” teaching and learning requires a more strategic and continuous approach to monitor the teaching and learning process, how students engage with the content and how they apply their knowledge in learning activities. This shifts the assessment paradigm from a summative test and exam approach, to a more formative, real world, and continuous assessment that focuses on the students experience. It shifts the focus from assessing **products** to assessing the **process** of learning [11]. Black and William [12] state, “... assessment becomes formative assessment when the [results are] actually used to adapt the teaching to meet student needs.” This strategy of formative assessment can often result in a more holistic understanding of the student learning experience [13].

In this paper, we will report on a qualitative action research study [14] conducted across multiple sections of a freshman level electrical and computer engineering circuits course (nine course sections, taught across four years by three different instructors). One section of the course, redesigned in 2014 by an instructor with seven years of experience (beginning in 2007) of flipped pedagogy experience, converted a traditional engineering lecture course into a flipped format active learning course. After piloting this course, the flipped format was expanded to include multiple sections of the same course that were taught by two other instructors, who had taught this or very similar courses for many years. Since this was a new approach to teaching in the department, it was important to gather student data not only about what students were learning in the course, but also about how they were learning, and how they were adapting to the new flipped course format. Action research methodology were selected for this study, because it is a method commonly used across many disciplines to study educational issues related to curriculum change with a purpose of examining teaching practice, documenting the continuous student learning experience across the semester, and also using data collected to improve the curriculum [15].

II. Literature review

A. *Flipped teaching and learning*

A flipped teaching approach, used in both K-12 and higher education, moves the lectures outside to a pre-class activity so that more active learning activities can take place in the classroom [16]. The benefits of flipped instruction have been documented in the literature as providing opportunities where students have more time with the faculty member, more time to interact with and learn from their peers, and more time to ask questions and clarify concepts in class [17]. Advantages for the faculty member are that they can witness in real-time where students struggle, identify learning bottlenecks and address them with the class, and incorporate just-in-time teaching strategies [18]. There are also disadvantages documented in the literature. Faculty lose some control over the presentation of content as they focus on student needs and just-in-time instruction where helping students learn may become more important than the content covered [19]. There are also disadvantages for students, because they must become more self-directed learners and take more responsibility for their own learning. Students can resist this new

responsibility and sometimes complain of having to teach themselves [20]. Flipped teaching and learning research can be found across many different disciplines, course levels, and in many different types of courses [21]. Most of the research on flipped teaching and learning focuses on the impact of the flipped classroom on student learning outcomes [10], [22], or compares the flipped classroom to traditional lecture courses [23]. This evidence-based research project, however, focuses more on how students engaged or disengaged across the semester while learning in the flipped classroom and how they adjusted to the flipped classroom experience. As researchers, we were more interested in using reflection at strategic intervals across the course, and continuous monitoring in the form of formative assessment, to see if the student experience changed. The use of reflection utilized the integration of the student voice to help improve and adjust the course content and delivery [24]. We believe that these observations can be very helpful for faculty who are contemplating or have already flipped their courses.

Active learning strategies are a key component to a successful flipped classroom. Active learning engages students in applying course knowledge and focuses on the doing of learning [25]. Springer et al. [26] conducted a meta-analysis of 37 studies of STEM classes and determined small-group learning experiences had a positive impact on student learning. Other researchers claim that active learning can improve student attitudes about learning and result in increased gains in learning [27], [28], [17]. Literature claims that student-centered teaching methods that include active learning can lead to better learning outcomes such as academic success, improved learning attitudes and increased student persistence than traditional teacher-centered methods. This study focuses more on the process of learning than the outcomes of learning. How do students say they learn in a flipped environment? What do they say they do as they learn? What helps and hinders their learning process?

A. Formative assessment

An integration of both formative and summative assessment is needed to get a holistic picture of the student experience [29]. Summative assessments such as exams and quizzes are critical tools and instruments to assess student knowledge and document growth across the course. Formative assessment strategies such as regular open-ended questions and low-stakes practice can be used to adjust and improve teaching and learning in real time [12]. Chickering and Gamson [30] encourage contact between faculty and students as well as active learning and recommend faculty give prompt feedback to students. Regular formative feedback can be a starting point setting the stage for active teaching and learning [31]. Reflective formative feedback can also help students become more proactive learners by providing opportunities for them to learn about how they learn [32]. In addition to formative reflective assessment, in class activities and integrated peer feedback can provide opportunities for students to learn from as well as teach their peers [33]. Students who reflect on their own learning process become metacognitive thinkers who know what works for them and therefore become more effective learners [20],[34]. Through the formative assessment process, faculty and students can create an opportunity for developing more personal relationships that can lead to a richer educational experience. Teaching practice using formative feedback strategies also benefits faculty by providing opportunities to informally assess in real time, customize the student learning experience and make adjustments to their teaching based on evidence collected in real time [35]. Nicole and Macfarlane-Dick [36] claim that for faculty “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).

The process of continuous formative assessment using student reflection data that was designed and implemented in this course can be adapted to other learning contexts in other disciplines. Collecting student reflection data incorporated the student voice into the traditionally faculty centered teaching process, and resulted in personal and insightful feedback that helped students think about their own learning process [37],[38], [39]. If students engage in the learning process and take more responsibility for their own learning, it can enhance their motivation and commitment for deeper learning [40] and increase metacognitive awareness about their own learning process [20]. Shultz and Cook-Sather [41] claim that dialogue between students and teachers can improve the culture of the learning environment. The student voices in our case study were critical, both for improving the class, and also for understanding the student experience as they encountered the flipped class for the first time.

III. Research methodology

A. Data collection process

This paper describes a qualitative action research project that uses a simple, efficient formative assessment approach that integrates regular open-ended survey questions in optional assignments across the semester to uncover student experiences and improve the course. Data about the learning experience and learning challenges were collected every 3 weeks in the learning management system as open-ended answers to optional assignments. The feedback was not anonymous, and students received a small amount of extra credit for completing the formative assessment / reflection. This strategy was initially intended to provide feedback to the faculty member, who was teaching the course for the first time, and flipping it as she went. The open-ended questions she asked were specific to what she wanted to know about her teaching at the time. Every assessment also asked “What can I/You do to help you learn better?”, which provided an opportunity for students to reflect on and consequently take more responsibility for their learning. It also provided a positive forum for students to voice feedback and concerns and even to provide recommendations. The assessments helped the faculty member improve the course in real time and adjust as student concerns changed across the course. With this approach, the instructor identified a number of bottleneck concepts, where a significant number of students were having problems. She also adapted several aspects of her teaching throughout the first semester (such as doing more complex problems in class, providing numerous additional examples, reviewing lecture content very briefly at the start of class, insisting and working on extracting key questions during class time, etc.).

Since the student feedback opportunities across the semester were voluntary and focused on different aspects of the course, not all students participated on each each question. However, 578 students were enrolled in the 10 sections of the ECE 1250 course that ran from 2014-2017 and of those students, 392 students participated in at least one of the formative assessment extra credit opportunities. One thousand and eighty-four responses were collected; 520 collected between

weeks 1 and 3; 222 responses between weeks 4 and 6; and 342 responses collected between weeks 7-9. The average participation rate across the classes for participation in at least one of the feedback commenting opportunities was 66.3%.

Data were collected roughly every 3rd week on different topics. In week one students provided personal information about their styles of learning and engineering interests. Every week students provided ‘Muddiest Point’ feedback about the concepts and content they were struggling with [4]. Additional feedback responses were collected about exams and quizzes, the lab section of the course, career planning and goals, and end of semester comments. In addition, data was collected in weeks 3, 6 and 9 about the student learning experience asking questions like, “How is it going? What resources work best for you? What can I/you do to help you learn better?” This data (weeks 3-6-9) were the data used for this action research project. An overview of the full formative assessment collection strategy is outlined in Figure 1.

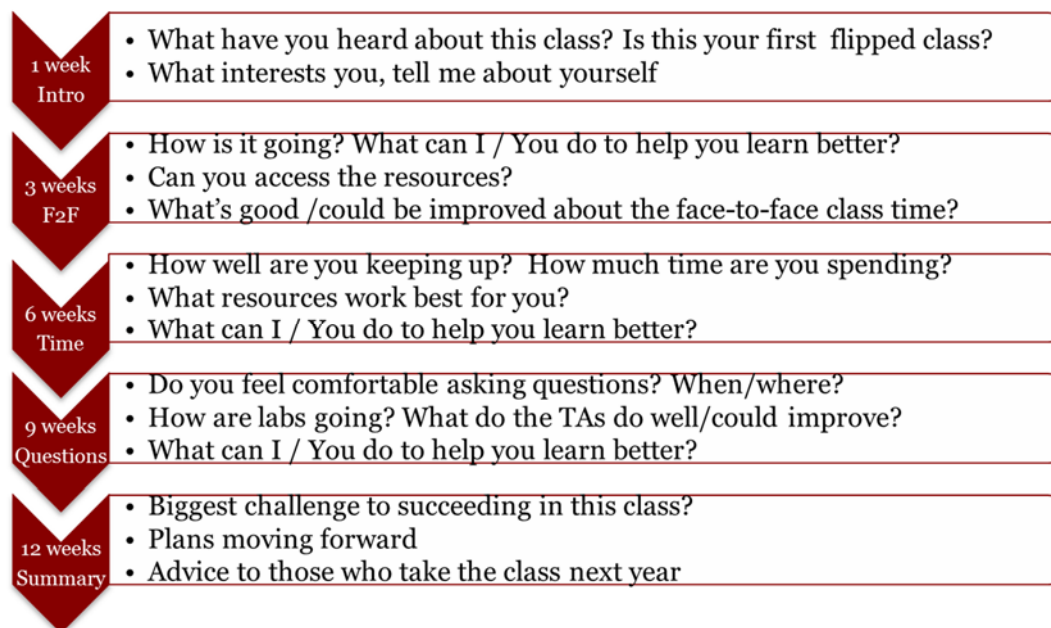


Figure 1 Formative Assessment Data Collection Overview. Data from Weeks 3, 6, and 9 were used in the study reported in this paper.

B. Data analysis

Data from weeks 3, 6 and 9 open-ended comments were downloaded from the Canvas LMS. The feedback was provided in a variety of formats -- PDF, excel, or text format. There were 10 sections of the ECE1250 course, taught over 4 years by 3 different instructors. Files were categorized as week 3 – beginning of course, week 6 – mid-course, and week 9 – late course. These files were then uploaded into the Macintosh version of NVivo 11, a qualitative text coding tool for conducting qualitative analysis.

Files collected in this study were analyzed using a grounded theory approach [42]. The student feedback text was coded line-by-line using an inductive qualitative constant comparative method of open coding with a purpose of identifying concepts and categories. Open coding, the first

stage of analysis, produced the basic units of analysis, the codes for the qualitative study. Once all the feedback text was open coded, individual coding was consolidated into categories or themes. This stage of analysis, called the axial stage of qualitative coding, is where categories or themes are refined. A constant comparative process of coding, category formation, and theme development leads to the third stage of analysis, which is called selective coding. After identifying the coding category/themes that emerged from the data, a recursive process called selective coding was completed [43], [44]. This stage of the qualitative process involved seeking relationship between the codes, categories and themes. This final stage of analysis identified the critical components of the findings, resulted in a re-evaluation of the coding structure and identified a conceptual framework around which the other themes reside.

IV. Results

A. Phase 1 of the coding and category development

From the qualitative analysis of 1465 open-ended comments collected during weeks 3, 6, and 9 across 10 courses, 4 years, and 3 instructors several major themes emerged. The main themes that emerged from the coding line-by-line of the student responses are: 1) Learning Processes, 2) Flipped Learning Attitudes and Perceptions, 3) About the Course, 4) Recommendations, 5) Lessons Learned and 6) Labs. Table 1 shows the number of references, the amount of coding in each of the 5 categories.

Table 1. The Total Number of Codes found in Each of the Five Categories/Themes

Category/Theme	# of Sources Coded in each Category	# of Code References in each Category/ %of Total
Learning Processes	251	709 / 48.4%
Flipping Attitudes & Perceptions	217	264 / 18.0%
About the Course	151	233 / 15.9%
Recommendations	99	120 / 8.2%
Lessons Learned	53	72 / 4.9%
Labs	58	67 / 4.6%

Learning Processes was the category with the largest coding frequency (largest number of coded responses). Coding within this category related to preferences that students had about how they learn and how the course activities were supporting or not supporting those preferences. Codes in this category included hands-on interactive activities, impact of video lectures, social learning, learning resources, communication preferences, and cognitive processes. However, the most interesting codes were related to how students expressed their process of learning in the flipped classroom. They discussed how they attacked the ‘process of learning’ and the importance of a variety of different resources as they prepare for the face-to-face class and follow up with homework after class. Two examples of how students explained their plan to learn are:

“I watch the videos before class and I take notes on them. I usually read the textbook on the material shortly after the class lecture. I usually study alone, but I have studied with a friend once and we plan to meet once this weekend to go over anything that is confusing so far.”

“I enjoy watching the videos before we come to class, I feel like that is working well for me. It helps me get a better understanding of the material and lets me get questions before I come to class, then in class either my questions get answered or I’m able to ask them and get answers.”

The **Flipped Learning Attitudes and Perceptions** category, the second highest category, included positive and negative comments about flipping. They discussed their prior experience with flipping and were not shy about discussing what works and does not work for them. One student explains it is not that they don’t like flipping but ...”

“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.”

Another student responded in a different way,

“I really like the flipped classroom I feel that it really benefits me and that I learn more and I learn the material easier. Also, because the lectures are videos if I don't quite understand something I can re-watch it instead of falling behind or having to go way out of my way to get help and then catch up.”

The category of **About the Course** included coding related to faculty qualities, course structure, classroom environment, assignments, homework, and exams and grading. Students discussed the comfortable classroom climate, the connection of teaching style and engagement and how the grading scheme for homework helped learning. One student (when commenting on the complete/not completed grading scheme for homework) said, “homework grading relieves stress of doing it incorrectly - I can focus on learning.” All three faculty received kudos for their ability to deconstruct difficult content and questions as well as for their availability.

The major category, **Recommendations for Improvement**, contained all the codes related to the ideas students had for improving the course. The most common code related to the importance of problems and examples in teaching the circuits topics. As one student said, “you can never have too many examples”. Students also discussed a need for more real-world problems and problems that could connect what they do in lab with the lecture materials. Believe it or not, students asked for harder problems and examples to be worked in class so they were better prepared for homework and exams. Some also requested slowing down the pace of the class around those really difficult problems and examples or to go over material more than once so students have an opportunity to learn it better. The last type of recommendation centered on bringing the video lecture content more into the face-to-face classroom activities. One student said, “I feel like

doing a brief overview of what each video lecture covered before we dive into each topic might be beneficial to my learning as well as the learning of others in the future”. (This is one of many recommendations the professors have incorporated that appears to have improved the course.) Table 2 shows the frequency of the coding within each category or theme across the three data collection snapshots across the semester. The numbers vary because of the different question prompts that were used for each week (see Figure 1 for the question prompts). These were originally based on what the instructor was trying to improve about the course, or wanted to better understand about the student experience at the time.

The **Lessons Learned** category of codes was interesting in that students could articulate very well what they did that they would have changed about their learning. This category of codes also included coding related to learning challenges the students expressed. They self-identified time management and difficulty keeping up as two of the main issues. One student admits, “It's difficult to keep up and actually watch the videos on time but when I do I feel confident and understand the material much better”. Another student said, “I'm going to try to do better to watch the videos and read the book before coming to class so I can understand better what you're talking about and be able to contribute more in class.”

In the sixth category of **Labs**, students discussed the value of the hands-on experience that the labs provided. The codes about the difficulty of the labs appeared very mixed, some students saying they were too hard and there was not enough time to do the labs, and other saying the labs were too easy and not really worth going to. This was perhaps not all that surprising, given the extremely broad range of previous experience the students brought to this, their first freshman circuits course. Students that talked about the connection or lack of connection between the labs and lecture, but the highest number of code frequencies were related to needing more detailed instructions about labs. This recommendation has also been taken to heart, and the lab write-ups have been improved each year.

Table 2. Coding Frequency/Instances Numbers by the week categories

	Week 2-3 (Flipped Experience)	Week 4-6 (In-class Activities)	Week 7-9 (Engagement & Resources)
Learning Processes	365	162	147
Flipped Learning Attitudes and Perceptions	129	48	77
About the Course	103	63	51
Recommendations for Improvement	55	21	43
Lessons Learned	16	20	28
Labs	21	21	18

B. Additional coding results

In addition to the open-ended questions that were coded and categorized, one of the professors, in only one section of the course, also asked some additional questions based on challenges and issues that she saw emerging across the semester. She wanted to know in more detail about how

students preferred communicating with both her and their peers. Table 3 shows how the percentage of students who asked questions and communicated with both the professors and other peers. Students with *Higher scores* were those who had a 75% or higher composite grade in class, the *Lower scores* were those who had a 74% or lower composite grade in class. In this same section of the circuits course, students were also asked about the value of the resources that were available to use in the course. In lab, students felt most comfortable asking questions. Students with a lower grade in the course also felt more comfortable asking their peers questions than students with higher grades. Table 4 provides the percentage of students who felt how valuable each resource was. Video and lectures were deemed to be the most valuable by students with both higher and lower grades.

Table 3. Comfort Level with Asking Questions

Final Grades?	To another student in class	Raising hand in class	Online discussion board	By email	To instructor directly	In Lab	TA tutoring	Don't ask: figure it out
Higher	46%	27%	19%	15%	31%	73%	27%	27 %
Lower	71%	43%	19%	19%	29%	76%	15%	0%

Table 4. Which of these resources do you find most valuable to help you learn?

	Video lectures	In class examples	In class problem solving	Textbook	Online resources	Labs	TA	Professor's office hours
Higher	85%	85%	46%	58%	42%	65%	35%	27%
Lower	76%	62%	48%	62%	24%	43%	33%	19%

C. Phase 2 of the data coding and category development

After all of the text comments were coded and categories or themes developed, the second phase of data coding and category development focused on analyzing the relationship between the categories or themes. On analysis of the codes and categories the researchers wanted to look closer at the sub-categories and codes within the largest category of Learning Processes. This contained most of the coding related to the student learning experience. Students were very forthcoming in describing in detail how they prepared for class, what they did in class, and how they worked through homework and problems post-class. This was a very important finding considering that the structure of a flipped classroom is composed of Pre-Class work, In-Class work, and Post-Class work. The coded data was reexamined using the framework of a flipped classroom experience (Pre-Class, in-Class and Post-Class). Codes related to the student learning experience were included and codes not related to the student learning experience were eliminated from the analysis. Therefore, the researchers isolated the Learning Processes Data and any coding related specifically to student learning and perceptions and re-categorized the codes into the three-stage flipped learning framework.

Table 5. Re-categorized Student Learning Process Coding According to the Flipped Classroom Framework (* = most coding)

Flipped Components Coding / %	Main Sub-Categories
Pre-Class Work Codes (102 code instances / 24.4%)	<ul style="list-style-type: none"> ● *Impact of video lectures ● Being prepared for class
In-Class Work Codes (243 code instances / 58.3%)	<ul style="list-style-type: none"> ● *Interaction & active learning ● Social Learning ● Examples, exercises & homework ● In-class recommendations
Post-Class Work Codes (72 code instances / 17.3%)	<ul style="list-style-type: none"> ● *Lessons learned by reflecting ● Homework strategies ● Study strategies

V. Discussion and conclusions

Although we expected to see many codes and categories/themes about the student flipped experience, since the focus of this research was to uncover how students were experiencing the flipped classroom, we also learned about how students planned to learn during this course. Students reflected on their processes and strategies they were using for preparing for class, working in the face-to-face active learning class, and studying and doing homework after class. Almost half of all the student comments were codes related to students learning processes. Since the professors informed the students that they were interested in their feedback to improve the course and learn about how they were learning in the course, students appeared open to sharing their reflections, actions, needs and improvement opinions, even though the feedback was not anonymous.

A. Learning in a flipped classroom

The most important finding from this action research process came from students' articulation of the learning processes they were using. The course was structured in a flipped classroom format that contained three components: 1) pre-class digital lectures to watch; 2) in-class active learning exercises problem solving activities; and 3) post-class homework to finish or continue work started in the classroom. Students discussed their own learning processes in the same way. Perhaps this course structure helped students visualize their learning process and better articulate how they were learning since they could categorize their learning into these three components. In Table 5, of the three components of flipped teaching and learning, students reflected more on the in-class active learning piece of the framework with 58.3% of the codes focused in that area. The students in this study reflected most on the interaction and active learning component of the face-to-face classroom. Their second most prevalent value was placed on working through problems, examples and exercises guided by a faculty expert. The literature contends that students engaged in an active learning classroom work and in the act of doing learning and then reflecting on it, have better academic success [17], [45]. Jenssen, et al. [27] claim that it is the active learning component of the flipped classroom that can be attributed to improvements in learning. Other researchers have found other factors that impact improved learning such as the relationship with faculty and peers in the classroom [34], [46] and the focus on pre-class preparation [47].

In this study students reported that the online video lectures (in the pre-class preparation) have helped them not only prepare for the upcoming class but also to go back to the videos for studying for exams and clarifying concepts. One such student response is,

“The lectures are online, which gives me ample time to absorb the information they have. If I need the information, I can go back and look at the lecture instead of having to go through my notes. I don’t get bored in class because it is more interactive.”

Students also report they take notes and record questions while watching the video so when they come to class they can get those questions answered. One student said, “When I am studying video lectures and other study materials before going to a class, I usually try to understand them and make some questions that I hope would be answered in class.” Our analytics data indicate that students also use the videos after the class, presumably when doing homework or studying for exams. This accounts for the reason this pre-class activity has the highest frequency of coding of all of the pre-class sub-categories.

In the in-class component of the flipped classroom students discussed how valuable it was to do problems, see examples, learn from peers and interact with the professor. The coding with the highest frequency was in the interaction and active sub-category. Here students discussed how they felt the classroom climate made it safe to ask questions, learn with peers, and work on harder examples. The main recommendation from students for the in-class sessions was to do even harder problems in class so that they would be better prepared for exams. One student suggests, “I think going over harder problems in class would help overall. I think the examples we do are too simple, we could also start there but get into harder problems that are similar to homework problems. I think that would help with homework and tests.” Students also requested more details about problems and asked the professor to ‘share tricks and tips’ that would help them.

Data that was coded and related to the post-class experience of the flipped classroom experience was mostly in sub-categories around study strategies, homework issues, and lessons learned. As students worked on homework and problem solving they talked about the importance of managing their time, and reaching out for support from the professor and peers through office hours and email. This component of the flipped classroom had the smallest amount of coded text. Students discussed how they use the videos, handouts, and their notes to pull concepts together when studying. Most students shared that they study alone and use google to help them fill in gaps or questions. But in the flipped classroom context, it is very important for students to be organized, self-directed, and take responsibility for own learning.

However, the most interesting finding was how students laid out pathways and plans for how they attack learning in the flipped classroom. One formative feedback prompt asking how they are doing and how they are learning yielded 208 voluntary, self-reflective comments. Students described how they prepared for class, how they worked through problems, how they used resources, how they watched videos and how they studied for exams. In most cases students begin their pre-class work with watching the video lectures. Some take notes, some do not. Here is an example of one of the typical learning processes used by students,

“Primarily I am watching the lecture videos – mostly before class but sometimes after – and I am using the question of the day [an assignment to be completed before class] as a checkpoint to gauge my understanding. I occasionally take notes when I feel I’m learning something that I will need to remember/have written down. I have not used the selections of the textbook except for extra help. I usually do the homework after class and I study primarily alone, outside of lab. So far I would say my experience has been positive, though I am still adjusting to the structure of the class and how best to learn within it.

Some students also discussed how they used the textbook to fill in gaps, or notes and other online resources as they study or do homework problems. One student said,

“I study alone, I usually try to solve the homework problems with my knowledge alone, if I struggle or find that my answers were wrong. I usually just go over the steps again, because that’s usually where the mistakes are. If I still cannot figure it out, I watch the video and read the book. I found that to be the best way.”

Although students rely on different learning resources at different times, and for different purposes, we realized that most students report using all the resources made available to them in this class in some way. Lecture videos and in-class problem solving experiences are the most valued, but many use or as they say ‘skim’ the book as a supplemental learning tool especially during the pre-class preparation. In addition to these resources students also reported on the value of their peers in class, for participating in voluntary study groups, and as resources after class.

B. Teaching and learning practice implications

Gathering formative as well as summative assessment data can improve the communication channels for student-student and student-faculty relationship building. It is important to gather both types of data [48]. Students expressed appreciation that the instructors asked them for their views, and opinions. It became clear how important it is to ask students direct questions if you are really interested in understanding the ‘how’ and ‘why’ of the student learning process. As students reflect on their learning experience they gain insight on their own learning processes which helps provide motivation for learning [49]. The active participation in class can help build a community of learners so they can build learning confidence and academic success [50].

The power of reflection can help students see where they need to step up and take more responsibility for their own learning. Students in this study did begin to describe lessons learned as the semester progressed and they reflected on their own learning process. One student commented in one of the final reflections, “It really is up to the student if he or she wants to be successful in this class”. Another student wrote, “Honestly I have been playing keep up with all of my school work, since these past two weekends I have lost time to work on any of my school work. I really only spend the bare minimum to study. This is compounding the problems I am having and I realize this.” Some students made commitments to change their learning process

like this student, “I plan on doing a lot of practice problems and utilizing the resources on the canvas page in order to gain a better understanding. I’m trying to get into a position where I can be slightly ahead of the class instead of being behind constantly and trying to play catch-up. That’s my personal goal.”

The instructors made numerous changes to the course as a direct result of the assessments. The weekly Muddiest Point assessments, as well as working directly with the students in the face-to-face class, provided real-time observations of what content the students were struggling with. In addition to almost daily additions or corrections to explanations about various content, the instructors devised a number of creative ways of teaching some of the content, which are reported in [4]. These methods, combined, have increased the passing rate of the class.

Furthermore, because the instructors had selected the feedback questions based on what they were trying to improve about the course, they were prepared to respond directly to the student feedback. For instance, the use of Muddiest Point assessments came out of the feedback that while most students were comfortable asking questions in other formats, some students still were not comfortable asking questions face-to-face. The Muddiest Points invited questions in a different format that proved to be quite popular and insightful. The initial course survey that included a question, “Tell me something non-technical about yourself” resulted in several students self-identifying with learning disabilities such as dyslexia, color-blindness (an issue in electrical engineering labs), autism, ADHD, mild and profound deafness, test anxieties and more. The instructor sought help from the Center for Persons with Disabilities, and developed novel strategies to help these students learn, strategies that it turns out helped many other students learn as well. Another example was feedback on the labs and lab TAs, where it became clear that the students particularly liked being able to figure things out and “use” the lab ideas to build something new. Creative elements were added to each lab, and a final invention project was added to the class. Labs that weren’t working well were dropped. Another example was on the question the instructors were debating amongst themselves on the need (or not) to incentivize students with pre-class quizzes or other methods to get them to watch the videos. Feedback on how the students preferred to use the materials available to them showed that most chose to watch the videos not because of incentives but because they felt they needed the content. In spite of now teaching the same class in essentially the same format for several years, the instructors continue to use the feedback to change some elements of the course, continually seeking ways to improve the student experience and learning. For the instructors, this very simple assessment method has and continues to provide valuable insight into large and small things they can do to improve their course. Rather than wait for end-of-semester student evaluation feedback, when it is too late to make improvements, they have real-time feedback that gives them the opportunity to try out improvements, and try again if they don’t work out the first time. This makes every semester a teaching laboratory, where new ideas can be tried and tested. This makes every semester a little different, and keeps the interest of the instructors as they work to continuously improve their course.

C. Conclusion

The amount of formative feedback provided by students as they reflected on their flipped learning experience has provided formative data for the professors as they work to improve the

ECE1250 class as well as provided students with deeper insights into their own learning processes that helped them in this class and which they can take forward with them into future courses. The structure and expectations of the flipped learning classroom provided a framework for students to follow as they laid out their learning paths and plans for successful learning. Students reported changes in their reflections and took steps to become more self-directed learners. This formative reflection process also uncovered the challenges of teaching and learning in the flipped classroom such as time constraints, difficulty keeping up, challenging concepts to learn, and technical difficulties that faculty can use to improve the course and better guide students through the flipped classroom process.

In the future, it may be interesting to study if the student preferences for how they learn and what resources they prefer are different in other types of classes (small graduate classes, other STEM class, non-STEM classes, etc.) and if this varies with demographic. We did find some differences between learning activities of students who were being highly successful in the class and those who were being less successful, and it would be worth further assessing these differences to determine if there is truly a “best practice” for student learning in the flipped class.

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