Implementation and Critical Assessment of the Flipped Classroom Experience

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Chapter 2

Ideation to Execution: Flipping an Undergraduate Pre-Calculus Course to Create Significant Learning Experiences

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ABSTRACT

In this chapter, a flipped model is implemented in an undergraduate mathematics course. There is a need to enhance learning experiences in STEM disciplines and college mathematics courses. The authors seek to redefine the traditional relationship of instructor as the active conveyer of knowledge and the student as the passive receiver of knowledge. They discuss their efforts to plan and prepare for the course and their experiences with its implementation. The authors started with what they wanted their students to learn in the course. Prior to coming to class, students watched video lectures and completed pre-work assignments. In class, the authors incorporated group-work through peer-instruction and lab activities, and the use of a classroom response system. They present the results of their data collection, feedback from student response surveys. Among other results, the students realized the value of preparation and took an active role in the formation of their own learning experiences.

INTRODUCTION

In recent years, the teaching and learning of science, technology, engineering, and mathematics (STEM) disciplines have become a top priority at every level of the educational system—from K-12 schools all the way to undergraduate institutions (NSF, 2014). The need to prepare a competitive workforce that is qualified for highly technical jobs has become a major economic concern. According to a recent economic indicator, knowledge and technology intensive industries make up a growing
sector of science and technology fields worldwide. In 2011, of the 26 million U.S. jobs, approximately 20% of all jobs require a high level of knowledge within any one of the STEM related fields (Rothwell, 2013). Moreover, the United States relies on skilled workers within STEM related fields more than any other country in the world, making up about 40% of its gross domestic product (NSF, 2014). Although STEM competencies are greatly needed, it is not clear that the current or even the future workforce will possess the skills necessary to fill those jobs. Findings from the Department of Commerce (2011) suggest that, between 2001 and 2011, the overall growth in STEM jobs was three times faster than that of non-STEM jobs. Furthermore, by the year 2018, the United States will have approximately 1.2 million unfilled jobs because the workforce will either be uninterested in taking on STEM jobs or simply lack the skills to do so (Bertram, 2014).

STEM fields present inherent challenges to learning due to the specialization and technical nature of these fields. However, mathematics, unlike science, technology, and engineering fields, serves as a gatekeeper (Stinson, 2004) to other disciplines. Historically, mathematics has been a critical filter for many students. With mathematics as a gatekeeper, students have academic access to advanced courses within the discipline, access to other related disciplines, and better opportunities in the job market. Recent findings from the National Assessment Educational Progress (NAEP) report indicate that mathematics continues to be a challenge to students at all grade levels. Specifically for 12th graders, there were no changes in the performance on the national assessments in comparison to assessment performance reported in 2009 (NAEP, 2013). This suggests that many students may continue to struggle when they begin to study mathematics at the undergraduate level.

For some educators the solution is clear. If students are expected to overcome barriers in mathematics, they must develop a different kind of skill when they are learning the subject. As Bertram (2014) states, “[We must] help students develop the interest and the collaboration, critical thinking, and problem-solving skills necessary to succeed in the global economy. [We] must start by implementing interesting, relevant, rigorous, and hands-on STEM curriculum in schools” (Bertram, 2014). While it is essential to train students well at every level of their mathematics educational experience, it becomes even more critical at the undergraduate level. For many students, the undergraduate level may represent the last opportunity to take math courses before they leave the educational system and move into the job market. By 2018, STEM jobs will only make up about 5% of the U.S. economy (Carnvale, Smith, & Melton, 2011). At the undergraduate level, it is imperative that mathematics courses, serving as gateways to STEM fields, help students develop competencies, find agency in their learning, and make connections to other disciplines helping to make the content more meaningful.

This chapter draws from a two-year course redesign and implementation project at a four-year mid-sized open access undergraduate institution in the southeast. This chapter examines the ways in which an undergraduate Pre-Calculus mathematics course was first restructured using an innovative model of instruction called the Flipped Classroom Model (FCM). The FCM created a possibility for instructors and students to create a robust classroom experience and to help create more relevant mathematics content for students to learn. The Pre-Calculus course re-design was a result of our attempt at reforming (1) the assertive role that is taken on by instructors as the conveyers of knowledge and (2) the passive role of the student as the receiver of knowledge. The goal was to create, for instructors and students, a climate of possibility where these two roles are shifted in such a way that significant learning could occur (Fink, 2003). We relied on the notion that these possibilities would exist at the intersection
of students and instructors being open and curious to multiple approaches to problem solving and their willingness to work among a community of learners to exchange ideas to reach their goals (Brooks & Brooks, 1999). The organization of this chapter is as follows: (1) a brief discussion of the evolution of the flipped classroom will be given, (2) a discussion of why an undergraduate Pre-Calculus course was redesigned, (3) a description of how the Flipped Classroom Model (FCM) was implemented, and finally, (4) student responses to the effectiveness of the flipped course in their learning. This work is informed by the following research and subsidiary question:

1. How does one effectively re-design a traditionally taught undergraduate Pre-Calculus course to the FCM in order to positively impact student learning experiences?
   a. What components of a flipped Pre-Calculus course do students find most effective?

These questions not only take into consideration the broad challenges discussed earlier (as they relate to STEM fields) but also consider mathematics specifically to understand what aspects of a course could be meaningful and enduring for students.

The theoretical frameworks that guide this project are Fink’s (2003) model for course design and creating significant learning experiences, juxtaposed with Wiggins & McTighe (1998), Backward Design Model. These two models were used to help create meaningful experiences for students in the undergraduate Pre-Calculus course, allowing mathematics applications to be made relevant to their discipline of study (Small, 2002). A description of the technology used (Prensky, 2001) and activities designed to engage students in inquiry-based learning (McCollister & Sayler 2010; Wiggins & McTighe, 2005) will be discussed. Finally, a discussion of the preliminary assessment results that emerged from the first semester of course implementation, along with future directions for this project, is presented.

A major goal of this chapter is to share our experiences designing and implementing a flipped mathematics course in an undergraduate institution. For individuals considering this kind of work, this chapter is meant to serve as a guide, providing considerations that could be made. In the next section, a description of the FCM and how it became a movement in higher education will be given.

THE FLIPPED CLASSROOM MODEL AND THE MOVEMENT

The Flipped Classroom Model (FCM) is a hybrid learning and reversed teaching model that delivers instruction at home through interactive, teacher-created videos and then moves the work to the classroom. Moving lectures outside of the classroom gives instructors great flexibility to spend more one-on-one time with each student during actual class time. Students have the opportunity to ask questions and work through problems with the guidance of their instructors and the support of their peers, creating a collaborative learning environment. In this context, peer-instruction is essential. Through peer-instruction (Mazur & Crouch, 2001), students co-construct knowledge, make meaning together, and strengthen the areas where they have difficulty through debate, discussion, and hands-on activities.

The FCM was pioneered by the work of two veteran high school science teachers, Aaron Sams and Jonathan Bergmann, working to reach more of their students having difficulty in Chemistry. FCM has been implemented by many educators in K-12, and qualitative data that includes instructor comments and feedback supports its benefits. This
suggests improved student engagement, increase in test scores, and drop in failure rates (Finkel, 2012; Flipped Learning Network, 2012).

While the flipped classroom movement has its roots in K-12 education, it has increasingly grown in both popularity and utility in higher education. Many educators in higher education have adopted aspects of the flipped model, especially in the social sciences (Lage, Platt, & Treglia, 2000; Seaboyer, 2014; Walvoord & Anderson, 1998) where students are required to come to class having read specific book passages and, therefore, are already prepared to engage in deeper discussion. A form of the flipped classroom has been implemented as early as the 1990s in natural science disciplines such as physics (Crouch & Mazur, 2001; Deslauriers, 2011; Mazur, 2009). In one particular case, students were required to do some work on their own before coming to class and then work with their peers during class time. Many educators such as those from the University of Washington, the University of British Columbia, and the University of Michigan have used these instructional methods and observed a reduction in failure rates, increase in student attendance and engagement, as well as increase in gains in comprehension of underlying concepts (Berrett, 2012; Long, 2012).

In 2013, a team of experienced flipped educators, members of the Flipped Learning Network, and Pearson developed, F-L-I-P, a model for flipped learning (Hamdan et al., 2013). The acronym, F-L-I-P, describes four key features of a flipped classroom that will allow flipped learning to take place. According to the Flipped Learning Network, the flipped course should be comprised of: a flexible environment, a learning culture, has intentional content, and a professional educator (Hamdan et al., 2013). The goal in creating the model was to clearly differentiate the flipped classroom from the traditional learning environment. As defined by Hamdan et al (2013), the flipped classroom should possess:

- A flexible learning environment to accommodate both group work as well as individual work.
- Instructor flexibility as it relates to expectations for student timelines.
- A shift of focus on to the student, as the instructor guides the learning process by facilitating engaging and critical learning opportunities.
- Intentional choices, on the part of the instructor, about the educational content to be delivered and the method of delivery.
- Constant instructor observation of the students, provision of instructor feedback, instructor desire to improve instruction, and instructor openness to constructive criticism.

Interestingly, flipping a course in the field of mathematics is a fairly new endeavor in undergraduate institutions. In review of the current literature, there has been some work around restructuring College Algebra, Calculus, Statistics, and several other advanced mathematics courses (Abramowitz & Kathleen, 2014; Heuett, 2014; McGivney-Burelle et al, 2014; Petrillo, 2014; Talbert, 2014; Van Sickle, 2014). However, no empirical research has been conducted to show a widespread change in student learning. We believe that the role of an instructor is to guide and facilitate learning. The classroom methodologies that govern a pedagogical approach are driven by the vision and the goals instructors have for their course, the current student population, and available resources. Just as no two traditional courses are alike, there are also differences between flipped courses. Considering the benefits of a flipped course as defined by F-L-I-P, we asked ourselves the important question. “Why should we flip Pre-Calculus at our home institution, Georgia Gwinnett College (GGC)?”
WHY FLIP PRE-CALCULUS AT GEORGIA GWINNETT COLLEGE?

Georgia Gwinnett College (GGC), is an open access four year undergraduate college in the southeast United States. The first four-year college founded in Georgia in over 100 years, GGC opened its door in 2006 to just over 100 students. The school has seen remarkable growth since then and boasts of over 9000 students in 2014, almost 70% of whom are from Gwinnett County. Thirty percent of these students are part-time with a one-to-one male to female ratio. GGC has the most diverse student body within the University System of Georgia with students from over 100 nations, as can be seen from the distribution table with respect to ethnicity as of Fall 2013 (GGC, 2014a). Table 1 provides a percentage breakdown of the student population by ethnicity.

The student population is also diverse across age, with 16.2% of the degree-seeking students in the non-traditional age group and 65.7% between the ages 18 and 22. The institution currently offers 40 concentrations in 12 majors, teacher education tracks, and pre-health courses and is continually expanding. As of Fall 2013, STEM majors make up approximately 26.9% of all majors at the college (GGC, 2014b).

At GGC, Pre-Calculus is one of the prerequisite mathematics courses taken by all STEM majors.

We were given a unique opportunity to redesign selected sections of Pre-Calculus as a result of an institutional mini-grant that was received. We chose to redesign Pre-Calculus because we grew frustrated with aggregate course assessment results that showed students not making connections to the material covered in the course semester after semester. By redesigning the course, we hoped that we would begin to make a difference in what the students experience in the class and better prepare them for courses within their respective disciplines. Data compiled by the GGC Office of Institutional Research and Effectiveness in 2012 and based on 379 students registered for spring semester reported that the enrollment make-up of Pre-Calculus was as follows: biology students (33.8%), exercise science students (8.1%), information technology students (19%), and mathematics students (5.3%). Internal assessments over the past few years revealed key areas, which needed attention uniformly across all sections of the course. Some concerns raised by assessment reporting included the following: (1) course structure lacks an application orientation; (2) instruction fails to differentiate so as to keep students engaged and motivated throughout the semester; (3) students lack understanding of the underlying concept and work out problems just by repetition; (4) students lack problem-solving skills; (5) students are unable to make mathematical connections with their discipline; (6) students lack mathematical literacy skills and; (7) students are unable to complete Pre-Calculus, thus deterring them from continuing in the STEM discipline for the fear of taking a higher level mathematics courses.

With these challenges in mind for both students taking Pre-Calculus and faculty delivering instruction, this project presented a fertile ground to consider a different course structure. This work moves toward empowering students to take ownership of how they learn. It also shifts the role

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<tr>
<th>Ethnicity</th>
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<tbody>
<tr>
<td>White - Non Hispanic</td>
<td>42.4</td>
<td>American Indian/ Alaskan Native</td>
<td>0.2</td>
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<tr>
<td>Black - Non Hispanic</td>
<td>29.0</td>
<td>Asian</td>
<td>9.1</td>
</tr>
<tr>
<td>Hispanic</td>
<td>14.4</td>
<td>Other</td>
<td>1.2</td>
</tr>
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of instructors and helps them change how they approach reaching significant learning goals that they set out for students to reach.

AN APPROACH TO CONSTRUCTING SIGNIFICANT LEARNING GOALS

We aimed at designing a Pre-Calculus course that would change how students approached learning mathematics content and reform how students viewed their role in the classroom in relation to their peers and the instructor. The Pre-Calculus course that we redesigned followed the Backward Design Model (BDM) process introduced by Wiggins and McTighe (1998). The essence of BDM is to begin with the end in mind. One first envisions the broad goals they have for their students, followed by designing the assessments and learning activities that will support students as they work to achieve these goals. This ensures that the classroom experiences are focused towards an achievable set of outcomes.

Teaching mathematics at an open access four-year college, with a diverse student population requires all elements of F-L-I-P. At the onset of this project, we had to set broad goals of what we believe is important when taking a mathematics course. Our broad vision for students taking any mathematics course is that they:

1. Take an inquiry-based approach to learning concepts
2. Take part in regular discussions with their instructor and peers
3. Gain extra practice and guidance with the help of their instructors and other resources on campus (Ames, 1992)
4. Develop their mathematical literacy (Shepherd, 2005) and problem solving skills
5. Make mathematical connections within and across their discipline of study (Small, 2002)
6. Learn to use technology to enhance their mathematical thinking and understanding

Upon laying this broad vision for students taking any mathematics course, we then constructed learning goals, specifically associated with Pre-Calculus. In doing so, Bloom and Fink’s taxonomy of significant learning goals, depicted in Figure 1, was adopted to help construct our framework.

Bloom (1956) developed the classification of objectives into the cognitive, affective and psychomotor domains. His model was later revised to include active verbs (Anderson & Krathwahl, 2001). The cognitive domain particularly is widely used by educators developing new strategies in course design (Fallahi & LaMonaca, 2009). One can observe that Bloom’s taxonomy captures many of the aspects in the cognitive domain such as remembering and understanding facts. It also captures applying knowledge to situations and other rules by analyzing and evaluating different elements presented and creatively integrating them as needed. But there are limitations if we want to help students develop agency as it relates to their learning.

Reflecting back on the broad vision we have for students, we realized that our goals were not restricted to foundational knowledge, application, and integration as described by Bloom. Instead, our goals reached into new kinds of learning, which included students taking an inquiry-based approach to learning concepts, being able to take part in engaged discussions with their instructor and peers, and becoming active participants in their learning community. We believed that this would enable students to seek guidance, when needed, both in their class and the extended academic community. These particular aspects of the students’ learning processes are well captured in Fink’s (2003) taxonomy of significant learning goals.

We first asked ourselves two questions: “What do we want students to remember at the end of the semester?” and “What experiences do we want students to have in Pre-Calculus that would be enduring after the course is over?” Attempting to answer these questions required us to think about the flipped Pre-Calculus course in the long term.
According to Fink (2003), learning means change. He further states, “For learning to occur, there has to be some kind of change in the learner. No change, no learning” (p. 30). Fink’s (2003) taxonomy of significant learning outlines six taxa used to assess course content and higher order thinking. They are: (a) Foundational Knowledge, (b) Application, (c) Integration, (d) Human Dimension, (e) Caring and; (d) Learning How to Learn.

*Foundational Knowledge* encompasses all of the content and information that instructors want students to know. This serves as the baseline of what instructors think students should know and understand that is necessary for other kinds of learning to take place. *Application* helps students to engage in some kind of action. It includes the skills instructors believe students should develop that are useful. *Integration* allows students to develop intellectual power because they are able to see how concepts and ideas are interwoven. Integration also helps students to make connections between their work both inside and outside of school. The *Human Dimension* gives students an opportunity to learn something important about themselves. When this occurs, students are able to have a better understanding of themselves and others as it relates to learning, allowing for more effective interaction. The *Caring* taxon gives students an opportunity to develop feelings, interests, or values after a learning experience. When this occurs, students may later investigate topics on their own in order to make it a part of their lives. Finally, *Learning How to Learn* helps students learn about an aspect of learning itself.
Students may learn how to be a more effective student through best practices and work better in learning situations.

As a result of the significant learning goals taxonomy described above, we constructed our own significant learning goals for the flipped Pre-Calculus course. We made sure to address the broad course goals for Pre-Calculus that must be met, as outlined by the mathematics discipline at our institution. Table 2 depicts each significant learning goal within the taxonomy within the context of Pre-Calculus.

Once the significant learning goals were stated, we then sought to create learning activities and assessments that would be the key components of the course and that would target the significant learning goals. In the next section, a description of the flipped course components for Pre-Calculus will be provided as well as their descriptions.

**FLIPPED PRE-CALCULUS COURSE COMPONENTS**

In order for students to move toward significant learning and for instructors to reach their significant learning goals, certain components were necessary. The Pre-Calculus course that we envisioned had five key components: (a) a welcome letter, (b) pre-work, (c) student response technology and critical learning questions, (d) weekly lab-activities, and (e) assessments.

One of the ways that we worked to get initial buy-in from students when we delivered the flipped course, in what they expected to be a traditionally taught course, was to introduce ourselves through a welcome letter. A welcome letter was sent to each student registered to take the flipped Pre-Calculus course approximately a week before the start of the semester. The welcome letter outlined course expectations, the structure of the course, technology that would be used, and specific assignments that students had to complete on or before the first day of the initial class meeting. Chickering and Gamson (1987) suggest that when instructors set high expectations, it becomes a self-fulfilling prophecy. Students will rise to the demands that you place upon them. Keeping this in mind, we hoped that the welcome letter would help to set the tone for the course so that students would begin to see their role as active, rather than passive, learners.

**Table 2. Pre-Calculus significant learning goals**

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<tr>
<th>Significant Learning Goals</th>
<th>Description as it Relates to Pre-Calculus</th>
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<tr>
<td>Foundational Knowledge</td>
<td>• Remember the basic properties of exponential and logarithmic functions</td>
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<td>• Understand how linear, rational, exponential, logarithmic, basic trigonometric functions are used in related disciplines</td>
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<td>Application</td>
<td>• Be engaged in quantitative reasoning, that is, understanding the problem and applying knowledge to determine a solution</td>
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<td>• Make key assumptions to model data, produce results, and then interpret the results that feed back into understanding the problem</td>
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<tr>
<td>Integration</td>
<td>• Connect linear, rational, exponential, logarithmic, trigonometric functions with their widespread use in students’ discipline of study</td>
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<tr>
<td>Human Dimension</td>
<td>• Come to see their own special way of learning, use that to their advantage, see that they have unique contributions to their learning community that are valued</td>
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<td></td>
<td>• Communicate mathematically for themselves and others</td>
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<tr>
<td>Caring</td>
<td>• Be anxious to critically evaluate the quantitative material that they encounter regularly in their disciplines</td>
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<td></td>
<td>• Build a relationship with classmates and professor and know that the student and the professor are co-constructing knowledge and the professor is a facilitator of students learning</td>
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<tr>
<td>Learning How to Learn</td>
<td>• Learn about their own preferred learning style and use it to their advantage for future learning</td>
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Pre-work assignments are another important component of the flipped Pre-Calculus course. Pre-work assignments are assignments that students are required to complete ahead of time in order to prepare for class. This component of the course represents foundational knowledge for the significant learning goals. Pre-work encompasses video lectures, virtual explorations, review of content from the course textbook, and short writing activities. When students are assigned pre-work, it details an overview of important topics that will be covered, learning objectives, resources for reading, viewing materials for class, and guided questions that they are expected to complete. Once students have completed preliminary work, they have a baseline for discussion in class.

During class-time, students engage in peer-instruction, which entail unpacking or thinking deeply, about important concepts. This component of the course includes the human dimension, caring, and learning how to learn for the significant learning goals. Throughout class, students are asked critical learning questions to see if they understand the big ideas of concepts covered. Initially, students are polled using a dynamic student response technology to see how they answer each critical learning question. Once polling closes, the results are given to the class, but the correct answer is not revealed. Through peer-instruction, students then have the opportunity to discuss with each other what answer they selected and why they chose it. The instructor then re-polls students to see if there is a difference with their response after peer-instruction. When the instructor reveals the correct answer, it creates an opportunity to discuss with students what they were thinking and to do additional support work to reinforce correct approaches to problems. It also gives the instructor an opportunity to address any misconceptions that students may have about topics. The core idea for using critical learning questions is as follows: (a) all students must commit to a preliminary answer; (b) all students must talk to each other about the subject matter; (c) learning takes place through peer-instruction; and (c) the instructor guides the discussion and helps students to leave class each day with important take-aways from the lesson. This component of the course includes the human dimension, caring, and learning how to learn significant learning goals.

In our flipped Pre-Calculus course, weekly lab activities were used to help contextualize the content covered each day. According to the significant learning goals, lab activities represent application and integration. Briggs and Bennett (2010) suggest that there is a difference between a content-driven approach and a context-driven approach when teaching a course. On one hand, a content-driven approach to teaching a course prioritizes getting through mathematical topics, but leaves little room for showing students how those topics connect to the real world or even their discipline of study. In a context-driven approach, “applications drive the course and mathematical ideas are presented as needed to support the applications” (p. ix). Keeping these definitions in mind, one of the ways we sought to infuse meaningful contexts in the classroom was to design and utilize weekly lab activities from a context-driven approach. During the weekly lab activity, students were required to apply the concepts taught each week to a real-life situation so that the mathematics used would be more meaningful and the classroom experience would be more relevant. The students were also given pre-work to prepare for the lab activities. Students were required to complete a formal report using word processing software, with a mathematical equation editor, to ensure that the mathematical syntax was correct. While instructors primarily designed lab activities, concepts for the activities were taken from multiple sources, including the course textbook, the web, and relevant situations from the media that could be explored mathematically during lab time.

One type of assessment that was used in the course was the examination. Excluding the final examination, exams consisted of two parts: an ap-
plication part, completed in-class, and an online portion that students completed on their own time within a three-day period. The application part of the exam was free-response and asked students to solve problems and then provide an interpretation of their solutions. The online portion of the exam covered foundational knowledge and included objectives like solving or graphing trigonometric equations.

**COURSE IMPLEMENTATION**

Beginning in fall 2012, we developed course materials for one year in preparation for the implementation of the flipped Pre-Calculus course. In spring 2013, an initial pilot of selected activities was implemented in two course sections. There were two instructors who primarily taught these sections, with an average of 25 students in each section. Two sections of the flipped Pre-Calculus course were also taught in fall 2013, followed by four sections in spring 2014. In fall 2013, each of the two instructors taught one section of a flipped course and one section of a traditional lecture course. Both sections of the flipped course in fall 2013 were taught three days a week. This was done intentionally to maximize contact time with students. There were two instructional days and one lab activity day. The instructor and a teaching assistant facilitated each lab activity. The teaching assistant was selected based on a recommendation by another instructor, as well as on the successful completion of Pre-Calculus with a grade of A in a previous semester. The teaching assistant also served as a support person for the instructor and students on lab days. In spring 2014, the two instructors taught the course following three different formats: three days a week class, two days a week, and one day a week. Table 3 summarizes the course implementation plan to date.

**DATA COLLECTION**

Students who enrolled in the flipped Pre-Calculus course, and consented to participate in the study, were asked to complete a free-response survey administered a few weeks before the end of the semester to determine their attitudes about completing pre-work, lab activity assignments, and using the student response technology (n=48). We chose to use a free-response survey so that students could express their feelings about the course in written form.

**RESULTS**

Findings from the free-response qualitative survey of fall 2013 and spring 2014 are presented. Furthermore, the results presented in this section will be a response to the overarching question, *How does one effectively re-design a traditionally taught undergraduate Pre-Calculus course to the Flipped Model in order to positively impact*

<table>
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<th>Table 3. Flipped Pre-Calculus implementation by semester</th>
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<td><strong>Fall 2012</strong></td>
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<td>Course Material Development:</td>
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<tr>
<td>• Pre-Works</td>
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<td>• Lab Activity</td>
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<td>• Video Lectures</td>
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student learning experiences? and subsidiary research question, What components of a flipped Pre-Calculus course do students find effective? There were four themes that emerged from student survey responses: (a) Preview and Preparation; (b) Building Classroom Community with Peers, (c) Improved Mathematical Communication, and (d) Playing the Game of Learning.

**Preview and Preparation**

When students were asked the question, “How did the pre-work assignments aid in your learning process in this course?” several responded that it helped them to see what would be covered in class, before it was actually covered. Students seemed to like the idea of knowing what was to come in regards to topics that would be discussed in class ahead of time. One student wrote, “It made sure you knew the work before you got to class!” Another student stated that, “They really helped me. The assignments gave good examples that I could relate to other problems.” This response suggests that instructors can use pre-work as a scaffolding tool. Instructors can preview fairly simple problems in pre-work assignments and build students’ confidence to work on more complex problems once they get to class.

**Building Classroom Community with Peers**

Several students seemed to enjoy the classroom experience with fellow students that resulted from the incorporation of pre-work and lab activities. Students were prompted with the question, “How did the pre-work and lab activities alter your classroom experience?” Many students stated that they really enjoyed the engagement with other students. One student stated, “It made it better because we interacted with our classmates, so we get to know each other more and it was easier to ask questions.” Some students seemed to like that, along with having more interaction with their peers, the structure of class was broken up and they were able to expect something different on each meeting day. A student wrote, “They changed up the order of how class went for that day. Like on Fridays, instead of the daily lecturing, we got to interact with classmates and that made the class more enjoyable.” Another student valued working in groups because groups allow for the opportunity to communicate with group members and see other ways of solving problems. It is important that students build community and feel comfortable reaching out to other students that are around them, particularly when they are learning mathematics. Working with others helps students move away from self-imposed stigmas of inadequacy when they are not sure how to do or approach solving mathematics problems. Working within a community of learners helps to build student confidence.

**Improved Mathematical Communication**

Students were asked the question, “Did the pre-work and lab activities help improve any of your skills in reading/writing mathematics and oral mathematical communication and how?” Some students reported that as a result of the requirement to complete pre-work and lab activities using word processing software with an embedded mathematical equation editor they were better able to write mathematics with technology. One student also reported an improvement in both their mathematical reading and writing skills, writing:

*They helped in all of the above. I read the textbook after listening to video lectures and I can understand more. When I write equations in lab activities, I can see better what exactly I am calculating. The pre-works usually asked me to write in my own words about definitions and stuff too. Moreover group discussion in lab activities help[s] the oral math communication.*
Supporting this statement, another student echoed that they were better able to communicate with their lab peers. The student wrote, “We had to have a basic understanding of it to communicate with our lab partners.”

**Playing the Game of Learning**

A common theme among several survey respondents that emerged from the data was that, as a result of enrolling in the flipped Pre-Calculus course, students experienced a new way of learning. Rather than “playing the game of school” and doing work just for work’s sake, students saw that by completing their work ahead of time and exploring with additional course materials, they learned that they would ultimately be better prepared for class. When asked about pre-work and lab activities, one student wrote, “[It] helped you focus on the material you would be learning instead of just not thinking about the class until you showed up.” Another student wrote, “[It] made things easier when you did them, but much harder when you didn’t have time to do them.”

Here, students recognized the value in preparation and had a better experience in class when they were prepared. Students also realized that learning is active and requires you to be present. One student stated, “It forced me to be more engaged in learning; ultimately that is a good thing.” This suggests that students were learning to take on a more active role with their learning as opposed to the passive role they may have previously assumed. This is underscored further by the following student statement, “It made me spend more time learning the material than I usually would have. They were beneficial.”

**DISCUSSION OF FINDINGS**

The emerging themes from our above-reported data links back to the significant learning goals we hoped our student would achieve. The first theme, *preview and preparation*, can be linked to the significant learning goal of foundational knowledge. In order for students to be successful during class time, they had to make the initial time investment and obtain fundamental knowledge of the content before class. Foundational knowledge requires students to remember and understand basic concepts before delving deeper into the work later.

The emergent second and third themes, *building classroom community with peers and improved mathematical communication*, can be linked to the significant learning goals of application, integration and human dimension. The pre-work and lab activities required that students investigate, analyze and articulate mathematics orally as well as through written communication. The class time was used to create a possibility for meaningful peer-to-peer and student-faculty interactions. Students were able to engage with classmates to build relationships that were helpful when it was time for peer-instruction and completing lab activities.

The last theme that emerged, *playing the game of learning*, links to the significant learning goal of learning how to learn. The course design was intentional. Whether there were activities that required students to take an inquiry approach towards learning or a timeline for submissions that required proper planning and preparation before class, these tools helped to foster good learning habits that students could potentially use in future courses.

**FUTURE RESEARCH DIRECTIONS**

We plan to implement the third semester of the flipped Pre-Calculus course in fall 2014. We recruited five faculty members to pilot selected course components and are currently working to train them to implement the flipped model of instruction in their own Pre-Calculus courses.
Ideation to Execution

Some will pilot these components during summer sessions, and others will pilot in the fall semester. We have also refined the project based on student feedback and assessment from both fall 2013 and spring 2014 semesters. Changes made to the curriculum before fall 2014 include refining video lectures and critical learning questions and creating more relevant lab activities. We have taken the above-mentioned steps as part of the effort to better capture reaching the significant learning goals we set out to achieve.

CONCLUSION

Since the Flipped Classroom Model is relatively new in higher education, it will take some time and further research to determine if it is truly an effective pedagogical approach when teaching mathematics courses to students. At the onset of this project we were ambitious, but hopeful that we could help shift how students viewed mathematics. More importantly, given the right tools, we also wanted to help empower students and shift how they learned mathematics. It is our belief that students will meet expectations; no matter how high they are set. By this, we mean that students will produce whatever is required of them as long as instructors believe that the students can do the work and continue to set high expectations for them. As simple as this idea may seem, it creates promise for not only educators, but also for students. Students can begin to take ownership of their own work, be engaged inside/outside the classroom, and work as a community of learners as we all move towards significant learning together. If we, as educators, can accomplish this, then we have taken a significant step in the right direction of achieving the goals that we have for our students.

REFERENCES


**ADDITIONAL READING**


**KEY WORDS AND DEFINITIONS**

**Backwards Design:** Is a method used in designing educational curriculum where first the goals are identified, followed by the instructional methods to be used and lastly the forms in which those methods will be assessed.

**Lab Activity:** In the context of a mathematics classroom, a lab activity is defined as an in-class assignment where students explore the application of mathematics in various other disciplines of study. Similar to a chemistry, physics, or biology, these lab activities give students an opportunity to have active learning experiences so that they can make meaningful connections to the mathematics studied.

**Peer-Instruction:** The process where students reflect on a question posed by the instructor, commit to an individual answer and then discuss their thinking and answers with their peers. Students work together to support each other’s learning by becoming the center of the teaching experience.

**Pre-Work:** Is the work students complete and submit before class. It involves the students reviewing certain material, which may be videos or other assigned reading material, following which they are required to complete guided questions.

**Significant Learning Experiences:** Significant learning experiences are the things that students learn that have positive, substantial, long lasting effects on their personal and professional lives, which will enable them to make contributions to the different communities that they are connected.