IMPLEMENTING THE FLIPPED CLASSROOM IN PRINCIPLES OF BIOLOGY TO DETERMINE EFFECTS ON STUDENT ACADEMIC PERFORMANCE.

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ABSTRACT

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IMPLEMENTING THE FLIPPED CLASSROOM IN PRINCIPLES OF BIOLOGY TO DETERMINE EFFECTS ON STUDENT ACADEMIC PERFORMANCE.

AUGUST 2018

The purpose of this study is to determine the effects of using the flipped classroom model on academic performance as opposed to using a traditional lecture style method. Moreover, this study examines if lower achieving students perform differently than high achieving students when the flipped model is implemented. Researchers used the 2015 fall semester as a control year and all topics in Principles of Biology at Texas Woman's University were taught using traditional lecture. In the 2016 fall semester, two topics in Principles of Biology were taught using the flipped classroom model. Data from consenting participants were used from identical pre-and post-tests administered in both semesters. Results indicated that there was no significant difference in academic performance on the two topics taught traditionally in 2015 and using the flipped model in 2016. However, in 2016, participants did perform significantly better on test items taught traditionally as opposed to those taught using the flipped model. Results also indicated that lower achieving students improved at a significantly higher magnitude on topics taught using the flipped classroom model than did high achieving students.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

As an educator, the task is to take student objectives that indicate what the students need to learn for that lesson, differentiate instruction to meet the needs of every student, and assure that learning has taken place through a form of assessment. These are the main components of an effective lesson plan.

The learning objectives that teachers use to begin the lesson planning process come from the state standards for the subject and grade level taught. The Common Core National Standards have been adopted by a majority of states in the United States as a means to create a common and equal standard for all students as well as increase rigor in schools to prepare students for college more adequately (Wallender, 2014). Standards are increasing in rigor; however, the amount of instructional time has remained the same. This leaves educators with the problem of having the same amount of time to teach students more content and/or more rigorous content knowledge. This could be one reason that educators report time-management as an issue that can lead to feelings of dissatisfaction with the student-teacher connection and engagement, lack of motivation, and lower retention rates (Shukr, Qamar, & Hassan, 2016). As a result, educators and researchers seek solutions to this problem.

The *flipped* or *inverted* classroom is one approach that has been proposed as a solution to maximize time. The flipped classroom may be a solution to covering content

and still allowing time for more active learning that can occur during labs, simulations, and cooperative learning that have showed to increase critical thinking skills and engagement (Herreid & Schiller, 2013). Justifications for the flipped approach are mainly centered on using class-time for activities other than direct instruction or content delivery and instead dedicating class-time to activities such as, cooperative, problem based, and peer-assisted learning which all fall under the category of "active learning" strategies. In addition, it is suggested that the flipped classroom model can cater to a more diverse array of learning preferences by providing more teacher-student interaction in class (Bishop & Verleger, 2013). Also, diverse learners can benefit from the use of some of the features available during out of class assignments while viewing video lectures, such as the ability to pause and rewind. Since lectures can be automated effectively and the active learning techniques cannot, the flipped class is a possible solution to improve efficiency (Bishop & Verleger, 2013).

Background

The flipped classroom approach has been gaining attention with educators since 2012, much to the credit of two chemistry teachers from Woodland Park, Colorado, Jonathan Bergmann and Aaron Sams. Their book, "Flip your Classroom: Reach Every Student in Every Class Every Day," suggests a solution to the time-management problem, especially in the science, technology, engineering, and mathematics (STEM) disciplines (Schultz, Duffield, Rusmussen, & Wageman, 2014).

Bergmann and Sams began flipping their chemistry classrooms in the 2007-2008 school year because many of their students were missing classes in their rural school

district of Woodland Park, Colorado for travel and athletic events. Bergmann and Sams (2012) decided to use screen capture software to record all of their lectures, use the note- taking as homework, and reserve class time for labs and activities. Since Bergmann and Sams had an entire school years' worth of a chemistry lecture video library that students could access online whenever needed, they also found that it was helpful with students who were absent due to illness, moved in mid-year, or needed additional support. In a statement made by Sams, "The time when students really need me physically present is when they get stuck and need my individual help. They don't need me there in the room with them to yak at them and give them content; they can receive content on their own," (Bergmann & Sams, 2012, p. 4). Although Bergmann and Sams claimed initial results using the same tests from previous years showed positive results, their end-of-the-year evaluations showed little retention of information. This meant students scored higher in initial assessments for the short term but did not seem to remember information long term. This led to Bergmann and Sams' later development of the *flipped mastery class* which utilizes the videos and assignments for students to master concepts at their own pace, allowing for deeper understanding of the key chemistry concepts and is claimed by Bergmann and Sams to be a best practice (Bergmann & Sams, 2012; Foldnes, 2016).

The flipped classroom approach, although being implemented in an increasing number of classrooms due to the increase in rigor, standards, and expectations in education, has had little quantitative and peer reviewed research conducted in the area of performance of learning outcomes. However, studies show that with proper pedagogical

training, support, and resources a flipped classroom can provide the opportunity for increased engagement and foster the development of critical thinking skills (Peterson, 2016, Foldnes, 2016).

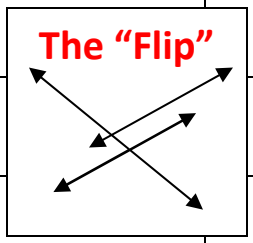
Definition and Distinction

In order to discuss a flipped classroom researchers typically start by comparing it to a "traditional" class. Table 1 illustrates the key differences in a traditional and a flipped classroom approach by showing the flow of a lesson. A lesson starts with the student learning objective, then Table 1 describes the typical activities for before, during, and after class to lead students from the objective to the summative assessment.

Table 1

Traditional versus Flipped Model of Instruction

Traditional Model of Instruction	**Flipped Model of Instruction**
Start with Student Learning Objectives for the lesson.	Start with Student Learning Objectives for the lesson.
Before Class:	**Before Class:**
	"Homework" Content Delivery by online videos and/or reading assignment
In Class: Content delivery	**In Class:** Practice content, extension of content
After Class: *"Homework"* (practice content, extension of content)	**After Class:**
Summative Assessment	**Summative Assessment**



A traditional class is defined in most studies as one where content is given in class via lecture or another form of direct instruction and then homework is assigned over the

delivered content in the form of practice problems or questions to be completed by the student on their own time, usually without assistance (Peterson, 2016; Butt, 2014; Shultz et al., 2014; Ryan & Reid, 2016; Munson & Pierce, 2015; Findlay-Thompson & Mombourquette, 2014; Foldnes, 2016; Gilboy, Heinerichs, & Pazzaglia, 2015). Defining the flipped classroom is complicated. This is due to the fact that not all "flipped" classes look the same. Some studies have flipped courses for an entire semester while others only flipped units of the course (Foldnes, 2016). Most define the flipped classroom as presenting concepts usually delivered in class through lecture as homework and using class time for "homework" (Peterson, 2016). To many, the course outline as far as student objectives, content material, and assessment do not look different in a flipped class than they do in a traditional class. However, the delivery of the content does look different (Butt, 2014).

A common trend in the literature is to associate the term *flipped classroom* with using videos to deliver lecture content as opposed to methods such as hybrid or blended courses, which can incorporate content through reading assignments (O'Flaherty & Phillips, 2015). While some define flipping as simply moving in-class activities out of class and *vice versa*, Bishop and Verleger (2013) said this definition is inadequate because it does not portray what instructors are doing in class, which expands the curriculum by incorporating student-centered, group based, and interactive strategies, instead of merely rearranging activities. The in-class activities are the key to success, or

lack thereof, when it comes to flipping a course (Foldnes, 2016). To define flipping just based on the use of video lectures is a mistake (Bishop & Verleger, 2013).

In order to reach more students, teachers in higher education have increased incorporation of classes that are online and blended (or hybrid) courses that include both online and face-to face class elements (O'Flaherty & Phillips, 2015). Some online class formats may require students to learn completely on their own with the aid of materials such as textbooks and could utilize internet and video resources. However, online classes may not allow for much interaction with the instructor, peers, or active learning strategies. Hybrid or blended courses require a combination of traditional instruction time in class and the possibility of using that class time for active engagement while still requiring an increase in the amount of content to be acquired outside of class time. However, the flipped classroom should not be defined as delivering content at home. If it were, then it would not be very different from an online or hybrid course. In a flipped classroom, the key to success lies in the utilization of face-to-face class time and what instructors are putting in place of the removed content lectures (Foldnes, 2016).

Effects on Academic Performance

After having discussed why some are choosing to flip their classroom and what the flipped classroom approach looks like compared to a traditional approach, the next question the researchers of this study had was what the effects of using the flipped classroom approach had on academic performance. As previously mentioned, the format of a flipped classroom can be diverse. For the purpose of this review, studies have been

categorized by the activities implemented during face-to-face class time, since it has been proposed as the key factor to a flipped classroom (Bishop & Verleger, 2013; Foldnes, 2016; Gilboy et al., 2015).

In two studies, active learning methods were defined as a range of engaging activities that have students doing something and thinking about what they are doing, were implemented during the in-class activities. Peterson (2016) taught two sections of college introductory statistics courses, one as a flipped class in which students were paired and worked collaboratively to complete assignments and one as a traditional lecture class. He reported that students in the flipped section improved their final exam scores by a full letter grade, with the $M = 82.3$, $SD = 14.3$ for the flipped section and $M = 72.0$, $SD = 13.2$ for the traditional lecture class. Students that participated in the flipped class reported overall to be more satisfied with the quality of the flipped course and the instructor on the voluntary end-of-course survey (Peterson, 2016). However, given that these groups were only compared in terms of grade point average (GPA) and class size, the question of whether these attributes alone qualify them as a good fit for comparison can be raised.

Peterson's (2016) findings of improved academic performance when using collaborative pairs during class are supported in a study by Foldnes (2016). This article analyzed results of two different studies performed over two years. A flipped classroom was compared to a traditional classroom both years with the first year (2012) comparing results of final exams from a traditional class to a flipped classroom with no collaboration

and working problems from the undergraduate statistics course book during class, labeled study one. Study Two (2013) compared a traditional undergraduate mathematics lecture class to a flipped class that incorporated a team-based learning format for in-class activities (Foldnes, 2016). Results indicated no significant difference in exam scores for study one but showed a highly significant increase (12 percentage points for both high and low performing students based on pre-test results) in performance in Study Two which incorporated collaborative and active learning methods (Foldnes, 2016).

In contrast, studies with flipped formats not incorporating active learning techniques or collaborative methods showed little to no significant change in academic performance (Ryan & Reid, 2015; Butt, 2014; Shultz et al., 2014; Munson & Pierce, 2015; Findlay-Thompson & Mombourquette, 2014). Ryan and Reid (2015) showed that there was no difference in performance or students' satisfaction in the flipped classroom versus the traditional classroom. Students were randomly enrolled in two section of general chemistry, with one being a flipped and the other a traditional section. Pre-test scores were used to identify three demographics of students for comparison (Group 1- pretest scores ≤ 40, Group 2- pretest scores 41-51, Group 3- pretest scores 52-70). Students were given five exams and an evaluation at the end of the course to assess satisfaction. Even though the study showed no significant difference in exam scores overall, it did show data that supported a significant difference for students identified as Group 1, or the bottom third, according to the pre-test on Exam 1 ($p = 0.032$) and on the overall exam average ($p = 0.037$). This study also showed a slight decrease in the number

of D's, F's, and withdraws given in the flipped section, indicating that the increased student-teacher interaction is a benefit to struggling learners (Ryan & Reid, 2015).

Unlike Peterson, Ryan and Reid (2015), where two sections were taught concurrently, Schultz et al. (2014) compared groups from two different academic years with the first academic year taught as a traditional class and the following year set up as a flipped section. This study compared academic performance by grade level and by gender. While they concluded that there was an improvement in academic performance, this was not consistent across grade levels (10th, 11th, and 12th grades). Only 11th graders showed improvement, and when data was broken down by gender, males showed significant improvement while females did not (Shultz et al., 2014).

Munson and Pierce (2015) conducted a study over three years (2012-2014) with entry-level pharmacy students enrolled in three different Essentials of Pharmacogenomics sections. The 2012 and 2013 sections were taught with traditional didactic lecture and the 2014 section was taught as a flipped course (Munson & Pierce, 2015). There was no significant improvement on exams scores between the traditional and flipped sections. Although data showed improvement on certain application-based questions in the flipped course, this cannot be contributed solely to the flipped model (Munson & Pierce, 2015). Results of this improvement could also be attributed to revision of lessons by the instructor due to analysis of assessment data made over the three-year period. Examples could include how the content was presented and practiced as well as changes to curriculum such as the order or flow, other than flipping to address issues that arose. In

addition, the groups of students in which results were compared were only identified as being similar groups based on having had similar grade point averages. No other similarities for justifying these groups were comparable were made or stated (Munson & Pierce, 2015).

A study with Findlay-Thompson and Mombourquette (2014) also indicated the flipped classroom had no effect on academic performance. Three sections of *Introduction to Business* were taught by the same instructor. Two sections were traditional and one was flipped. Course grades were compared as well as end of course interviews with open-ended questions asked to a judgment sample. All three sections had identical course outlines and grading scales. It was hypothesized that grades in the flipped section would be higher, but the average course grade for all three sections was a "B" with average grades for all three sections ranging between 73-76 (Findlay-Thompson & Mombourquette, 2014).

Evidence that the flipped classroom approach has improved learning outcomes or higher-level thinking skills has only been reported when the flipped classroom approach is combined with active learning activities during the face-to-face class time (Peterson, 2016; Foldness, 2016). When active learning techniques are not employed, the flipped classroom showed no significant improvement on exam scores and overall average performance (Ryan & Reid, 2015; Butt, 2014; Shultz et al., 2014; Munson & Pierce, 2015; Findlay-Thompson & Mombourquette, 2014). However, there is some evidence to support the concept that the flipped concept can help reach struggling learners (Ryan &

Reid, 2015). If there is no improvement on academic performance, are there other benefits or other skills that students acquire from a flipped classroom?

Although research shows little difference in academic performance in a flipped class versus a traditional classroom setting, there is evidence that perceptions of the class environment, engagement with material, and student satisfaction with the course are affected by a switch to a flipped model. In several studies, students were overall more satisfied with the quality of the flipped course and the instructor when compared to a traditional section (Peterson, 2016; Butt 2014; Shultz et al., 2014; Love, Hodge, Grandgenett, & Swift, 2014; Findlay-Thompson & Mombourquette, 2014). Students preferring the flipped class model when compared to a traditional model was also reported by a majority of students enrolled in a semi-flipped model conducted by Gorres-Martens, Segovia, and Pfefer (2016) that included some lessons being flipped while others remained taught in a traditional setting. Students referenced the features of viewing videos such as rewind and pause that they used while taking notes over lecture content as examples of why the flipped model worked better for them (Gorres-Martens et al., 2016).

Butt (2014) stated that feedback from end-of-course surveys showed students preferred a video lecture as opposed to being given a reading assignment. This article also stated that with the positive response to the flipped classroom, it is "worth pursuing in future years" (Butt, 2014, p. 41). However, more evidence is needed in areas of performance and skill attainment before such a claim can be supported. Video lectures

are just one small piece of the flipped classroom. If the purpose of removing direct instruction from the classroom is to create more opportunity for active learning, then the in-class activities should be the focus of the this approach. Many studies simply used in-class time for the flipped class to complete homework from the traditional class format. Future studies might focus on the development and types of in-class activities in a flipped classroom that take the place of face-to-face lectures, which may be where the real benefits of this model could be observed. Given that student perceptions of a flipped class have reported improvement over traditional classrooms, further investigation into implementing the flipped classroom methodology is needed. This is especially true in STEM courses where grades are reported to be lower, withdrawal rates reported to be higher, and there are also reports of less diversity among STEM majors (Tally & Scherer, 2013).

Effects on Student Perceptions

Although research shows little difference with academic performance in a flipped class without active engagement versus a traditional classroom setting, several studies have reported that perceptions of the class environment, engagement with material, and student satisfaction with the course does seem to be affected by a switch to a flipped model. Students were overall more satisfied with the quality of the flipped course and the instructor when compared to a traditional section according to Peterson (2016), which he claims could have correlated to the increase in academic performance reported in this study, as well. Increased perception of the flipped class model was also reported by a

majority of students in flipped section versus a traditional section by Schultz et al. (2014) and Love et al. (2014), and with a semi-flipped model conducted by Gorres-Martens et al. (2016). However, the flipped classroom was not rated as high on course evaluations by females in this latter study as it was with the male population. This also correlates to the results of an increased performance in males and no significant difference in female student performance with this study (Shultz et al., 2014).

In addition to academic performance, researchers have started focusing on what other benefits students could obtain from this model. A study by Butt (2014) set out to address two questions about the flipped classroom. First, do students value traditional lecture and other formats of learning and, second, what are students' perceptions of the flipped model after experiencing it? Students in a senior level *Actuarial Technique* course were given enhanced and lengthened versions of class notes to review at home while class time was used to go over exercises in the notes with group members and the instructor circling to address student questions. Participants were given two voluntary surveys, one at the beginning of the semester and one at the end, with a Likert scale series as well as open response questions. Survey results showed that students feel they learn best through performing an activity as opposed to reading or listening to lecture, but also prefer lectures and individual work over group activities according to part one of the survey. Part two of the survey revealed that after being exposed to the flipped class model, eighty percent of students gave positive feedback on open-ended response questions and stated they were able to receive the help they needed even though before

taking the class they had concerns about receiving clarification and the opportunity to address questions throughout the course (Butt, 2014).

In contrast, in the 2014 study with Findlay-Thompson and Mombourquette, out of seven students interviewed, four spoke positively about the flipped classroom while three preferred a traditional class. Students in this study were given end of course interviews with open-ended questions administered to a judgment sample. They chose to interview students because it allows for better understanding, greater depth with responses, and more detail. What was interesting is that even though some of the students preferred a traditional class setting, all but one said they would consider enrolling in future courses that were flipped. The only student who would not consider taking another flipped section was the only student interviewed that was categorized as a non-traditional "mature" student.

Significance of this Study

Although the flipped classroom model is being used more widely in classrooms, there is still not a significant amount of research in the area of academic performance. More studies have been published regarding student perception of the model. Therefore, this study, which was approved by the Texas Woman's University Institutional Review Board, was conducted to determine effects of the flipped approach on academic outcomes and perceived student engagement. It was hypothesized that: (1) academic performance would increase more on test items taught using the flipped classroom approach than on test items taught using traditional lecture methods due to the implementation of active

learning methods used during the in-class time; and (2) students performing in the bottom third on the pre-test would improve more than students in the top third on the flipped topic questions than on the non-flipped topic questions from pre-test to post-test. This study evaluated the effects of the flipped classroom approach on academic performance in an entry-level undergraduate course when content was delivered as homework through video lecture and reading assignments. Active learning techniques, specifically the team-based learning model, were implemented during in-class time, and participants were compared based on individual growth on pre-and post-test administration. This methodology allowed for more accurate comparisons between groups, as well as adds to the limited number of research studies implementing active learning methods with the flipped classroom in collegiate classes.

CHAPTER II

METHODOLOGY

This research study was conducted in an undergraduate course, *Principles of Biology I*, at Texas Woman's University in the fall semester of 2016. Each class met two times a week for 1 hour and 20 minutes each with the fall semester of 2015 (N = 133) serving as the control group and the fall semester of 2016 (N = 147) serving as the intervention semester in which the flipped model was implemented. Two chapters of study were chosen from the curriculum to instruct using the flipped model after discussion with the Professor, Dr. Sandra Westmoreland. Cell anatomy and function will be referred to as flipped Topic 1 and mitosis will be referred to as flipped Topic 2. These units were chosen based on the criteria that they (1) were previously taught using traditional methods of lecture to deliver content in class, (2) had homework which was completed by the student outside of class, and (3) were also not previously taught using team-based learning.

Course Outline

Day One of the semester the research study was presented to the students and explained. The research procedures were made available to students and consent forms were handed out and collected as well as made available to students online to print, sign, and turn in later if desired. Only data of consenting students was included in this research study. Also on Day One of the semester, a 50 question pre-test was administered to all students to evaluate prior content knowledge on the concepts covered in the course.

The course outline, as shown in Table 2, was not changed from the control year to intervention year. All content was taught in the same order, given equal number of allotted days for instruction in both semesters, and assessed at the same time within the semester using the same assessment tools.

Table 2

Course Outline

Pre-Test		
Unit 1	Chemistry	Chapters 2, 3, 4, 5
Unit 1 Exam		
Unit 2	Cell 1	Chapters **6**, 7, 8
Unit 2 Exam		
Unit 3	Cell 2	Chapters 9, 10, **12**, 13
Unit 3 Exam		
Unit 4	Genetics	Chapters 14, 16, 17
Comprehensive Final Exam		
(Unit 4 Content and Post-Test)		

To develop the first flipped Topic 1, Chapter 6 of Unit 2, shown in red on Table 2, the content was evaluated as it was previously taught in the fall of 2015, which was used as control. Table 3 provides a comparison outline of how flipped Topic 1 was instructed in 2015 as opposed to the 2016 intervention year.

Table 3

Course Design for Control v. Intervention Semesters for Flipped Topic 1

Traditional Model of Instruction in 2015	**Flipped Model of Instruction in 2016**
Student Learning Objective for Chapter 6- Cell structure and Function: Compare and contrast the structure and function of (1) prokaryotic and eukaryotic organisms and (2) animal and plant cells, including the functions and inter-relationships of plant and animal cell structures including the nucleus, chromosomes, ribosomes, endomembrane system, mitochondria, chloroplasts, cytoskeletal fibers, extracellular structures and cell junctions.	Student Learning Objective for Chapter 6- Cell structure and Function: Compare and contrast the structure and function of (1) prokaryotic and eukaryotic organisms and (2) animal and plant cells, including the functions and inter-relationships of plant and animal cell structures including the nucleus, chromosomes, ribosomes, endomembrane system, mitochondria, chloroplasts, cytoskeletal fibers, extracellular structures and cell junctions.
Before Class:	**Before Class:** *"Homework"* Students assigned videos to watch and reading assignment to obtain content. Completed a pre-class assignment that went with videos and text.
In Class: Lecture with clicker questions to deliver content. Students used fill-in-the-blank notes during lecture.	**In Class:** Team-Based Learning Module: IRAT, TRAT, application activity (Case Study)
After Class: Mastering Biology Homework **Summative Assessment**	**After Class:** Mastering Biology Homework **Summative Assessment**

In 2015, the control semester, Chapter 6 was taught using lecture to deliver content in one class period while students used fill-in-the-blank notes that were provided, printed out, and brought to class with them. Students were then assigned to complete an online homework assignment in the companion *Mastering Biology* curriculum. To implement the flipped model for this chapter, students were assigned to watch videos

prior to class posted by Khan Academy (https://www.khanacademy.org) that delivered online content over cell anatomy and function. In addition, students were assigned reading in the textbook for content on the subject. Students were to use the combined resources of the online material and textbook to complete the pre-class assignment, which covered the same material and compared to the in-class fill-in-the-blank notes from the given in the 2015 control year.

In the Fall 2015 control semester, one class meeting was used to lecture over the cell anatomy and function. In the Fall 2016 intervention semester, lecture content was flipped and moved to a pre-class assignment which allowed for the one in-class meeting time to be used to engage in an active learning model. The team-based learning model was used for in-class time and the structure of that model was followed as presented in the guide by Michaelsen and Sweet (2011) and illustrated in Figure 1.

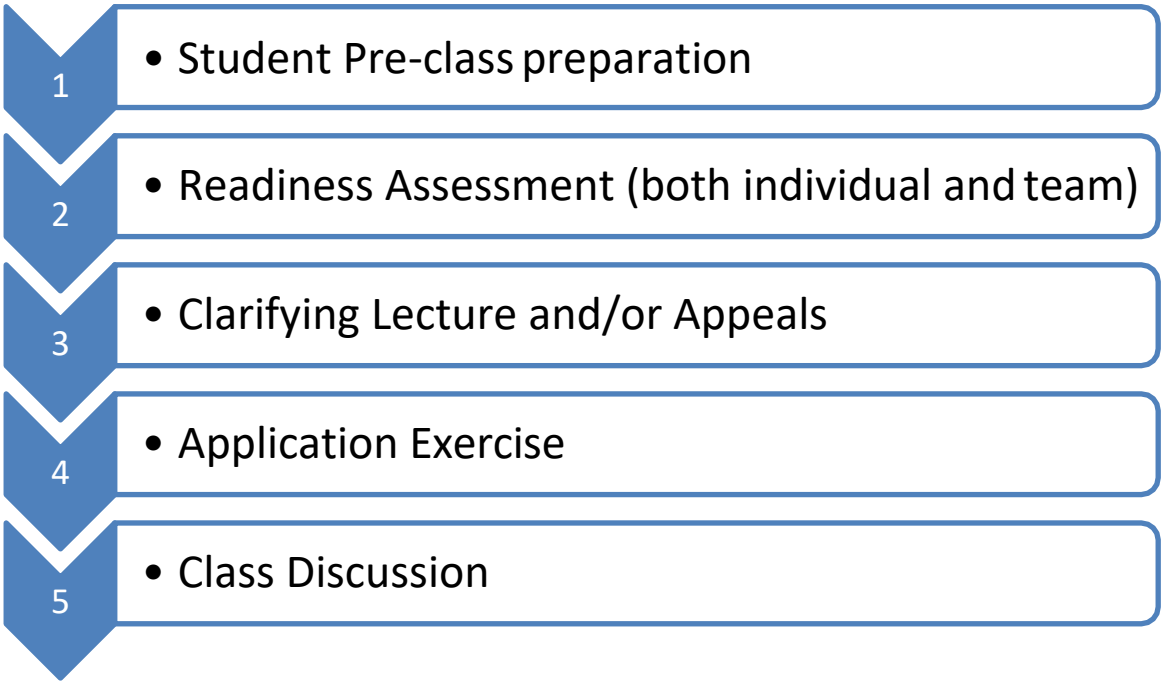


Figure 1. Steps in Team-based Learning.

Students began class time with an individual readiness assurance test (IRAT) in which they could use their completed pre-class assignment worksheet to complete. This was to give students additional incentive to complete the pre-class assignment and come prepared for the activity. The next step was to divide the class into heterogeneous teams of 7-8. Students in Dr. Westmoreland's class use the team-based learning model with other units, so students had been previously divided into groups in which they keep for the entire semester. Once in groups, the teams completed the team readiness assurance test (TRAT), which was the same test as they just took previously, but now they discussed it as a group and decided collectively what answer to choose as a team to record on a scratch off scantron and submit as part of their team grade. After teams

completed the TRAT, they began the activity that was to read and analyze a case study from the "National Center for Case Study Teaching in Science" website.

The case study "Little Girl Lost: A Case Study on Defective Cellular Organelles" (Hudson, 2015) was chosen to be presented based on the criteria for content, age appropriateness, relevance, and interest level. As a team, students read the case, completed the companion worksheet that analyzed and evaluated the case throughout different phases, and finally made a decision as a team about how to treat the patient presented in the case whom had a disease caused by defective mitochondrion and then created a treatment plan. To complete this case, students needed an understanding of cell structure and the function of its parts as well as how they work together. In order to present their team decision, each team made a poster they hung around the walls of the auditorium. Other teams did a gallery walk in which they explored the treatment plans presented. Each team was given one sticky note with their team number on that they were to place on the poster they think presented the best treatment plan. After all votes were cast during the gallery walk, the class was brought back together for a whole group discussion about the case, how it applied to the content of the course and pre-class assignment, and why they chose the treatment plans they did.

Table 4

Course Design for Control v. Intervention Semesters for Flipped Topic 2

Traditional Model of Instruction in 2015	**Flipped Model of Instruction in 2016**
Student Learning Objective for Chapter 12- Explain how mitosis results in genetically identical cells and identify the phases of mitosis.	Student Learning Objective for Chapter 12- Explain how mitosis results in genetically identical cells and identify the phases of mitosis.
Before Class:	**Before Class:** *"Homework"* Students assigned videos to watch and reading assignment to obtain content. Completed a pre-class assignment that went with videos and text.
In Class: Lecture with clicker questions to deliver content. Students used fill-in-the-blank notes during lecture.	**In Class:** Team-Based Learning Module: IRAT, TRAT, application activity (Case Study)
After Class: Mastering Biology Homework **Summative Assessment**	**After Class:** Mastering Biology Homework **Summative Assessment**

The second flipped topic, Chapter 12 of Unit 3, shown in bold on Table 2, was administered in a similar manner as the first and shown in Table 4. The content for flipped Topic 2 was also presented by lecture in one class meeting in the previous Fall 2015 control semester. An online homework assignment with the *Mastering Biology* companion component was assigned to be completed after class.

In the 2016 intervention semester, students were assigned to watch the online content over the concept of mitosis provided by Khan Academy (https://www.khanacademy.org) as well as read the textbook content to complete the pre-class assignment. This completed assignment could have been used to complete the IRAT that began the in-class structure of the team-based learning model.

Students then broke up into their teams, completed the TRAT, and began work on the activity that was a case study analysis of the case titled “Who killed Yew?” (Marsh, 2016). For this case, teams had to demonstrate their knowledge of the cycle of mitosis by discovering who the murderer in the case was and how the mitotic inhibitors they used worked to perform this task. They then applied this knowledge to how mitotic inhibitors are used in chemotherapy. As a team, the final task was to vote, given an explanation of the four main stages of breast cancer, which stage they would recommend chemotherapy being most effective for using their knowledge of how the drugs work and affect the cycle of mitosis. The whole class was brought back together at the end of class and asked to simultaneously vote for which stage their team chose by holding up a card with the number choices of 1- 4. Finally, a whole group discussion and debate was held to talk about how the case applied to the pre-class assignment in addition to defense of their team choices using citations from the case and pre-class assignment.

On the final day of the semester, students were administered a 100 question multiple choice final exam. On this exam, 50 questions were over content presented since the last exam, and 50 questions are classified as the post-test questions and are the same questions given on the pre-test exam administered on day one of the semester.

Data Collection and Analysis

To address hypothesis 1. Academic performance would increase more test items taught using the flipped classroom approach than on test items taught using traditional lecture methods.

Data was collected from the 50 questions on the pre- and post-test scores of consenting students in the fall semesters of 2015 and 2016 although all students enrolled in the courses participated in both pre- and in-class assignments and activities. Exam scantrons were graded for participants and an item analysis of both pre- and post-test scores was completed to determine overall averages for each question. Pre- and post-test question responses for Fall 2015 and Fall 2016 were entered into an excel workbook spreadsheet with a 0 indicating an incorrect answer and a 1 indicating a correct answer. Participants were assigned unique identification numbers and names were removed from the spreadsheet to maintain confidentiality.

Data was then transferred into SPSS statistics software for further analysis. Questions were marked as either flipped topic questions or non-flipped topic questions. Both pre- and post-tests consisted of an identical 50 questions set in which 10 questions were identified as flipped topic questions and 40 questions were identified as non-flipped topic questions. Participants enrolled in the fall of 2015 were marked as control participants while participants enrolled in the fall of 2016 were marked as intervention participants.

A paired *t*-test was conducted to analyze the 2016 pre-test to post-test scores for both the 10 flipped topic questions and the 40 non-flipped topic questions. Data was analyzed by using independent student's *t*-test to compare outcomes of the 2015 and 2016, 10 identified flipped topic questions to the 40 non-flipped topic questions. A Cohen's D calculator $(m_1 - m_{2)} /[\sqrt{(^s1^2+^s2^2)/2}]$ was used in all of these tests, as well, to calculate effect size.

To address hypothesis 2. Students performing in the bottom third on the pre-test would improve more than students in the top third on the flipped topic questions than on the non-flipped topic questions from pre-test to post-test.

Participants in both the fall of 2015 and the fall of 2016 were divided into three demographic groups of low, middle, and high achievers based on their pre-test scores. On the pre-test, a score of 0-0.3 were marked as a 1 or low, scores of 0.301-0.38 were marked as 2 or middle, and scores of 0.3801 or higher were 3 or high achievers. An ANOVA test was conducted to compare outcomes on pre-and post-test scores for both the 2015 control year and the 2016 intervention year to distinguish performance on the targeted lessons of low, middle, and high achievers.

CHAPTER III

RESULTS

Analysis to Address Hypothesis 1

Academic performance would increase more on test items taught using the flipped classroom approach than on test items taught using traditional lecture methods.

Overall Pre- to Post-Test Score Comparison for 2015 and 2016

Test question item analysis. First, questions were identified on the 2015 and 2016 pre- and post-test exams as either flipped or non-flipped topics, with 10 questions being identified as flipped topics and 40 identified as non-flipped topics on both identical pre- and post-test exams. The 10 test questions for flipped topics can be found in Appendix A. Although no topics were taught using a flipped model in the 2015 semester, items were identified on pre- and post-tests as flipped topics content to use as a control. Table 5 lists the 10 questions on the pre and post-test exams that were identified as flipped topic questions. All remaining 40 questions were marked as a non-flipped topic questions. F1 represents questions that cover the first concept that was flipped, the cell, Chapter 6 of Unit 2, and F2 represents questions that cover the second concept that was flipped, mitosis, and Chapter 12 of Unit 3.

Table 5

Flipped topic questions on pre-and post-tests

2015 Pre-Test	2015 Post Test	2016 Pre-Test	2016 Post-Test
11 F1	51 F1	11 F1	56 F1
12 F1	52 F1	12 F1	57 F1
13 F1	53 F1	13 F1	58 F1
14 F1	54 F1	14 F1	59 F1
49 F1	89 F1	49 F1	94 F1
50 F1	90 F1	50 F1	95 F1
35 F2	75 F2	35 F2	80 F2
36 F2	76 F2	36 F2	81 F2
37 F2	77 F2	37 F2	82 F2
38 F2	78 F2	38 F2	83 F2

Next, pre- and post-test exam scantrons of consenting participants were graded for both the control year, Fall 2015 $N = 133$, and the intervention year, Fall 2016 $N = 147$. An item analysis was done for both years recording the overall class percent average of participants getting each test item correct. Test question numbers 1 through 50 and the percent of students who answered each question correct were entered into a Microsoft Excel spreadsheet. Overall averages and standard error for percent correct on flipped topic test items (40 questions identified on Table 5) and non-flipped topic items (10 questions identified on Table 5) were calculated and results are shown in Figure 2.

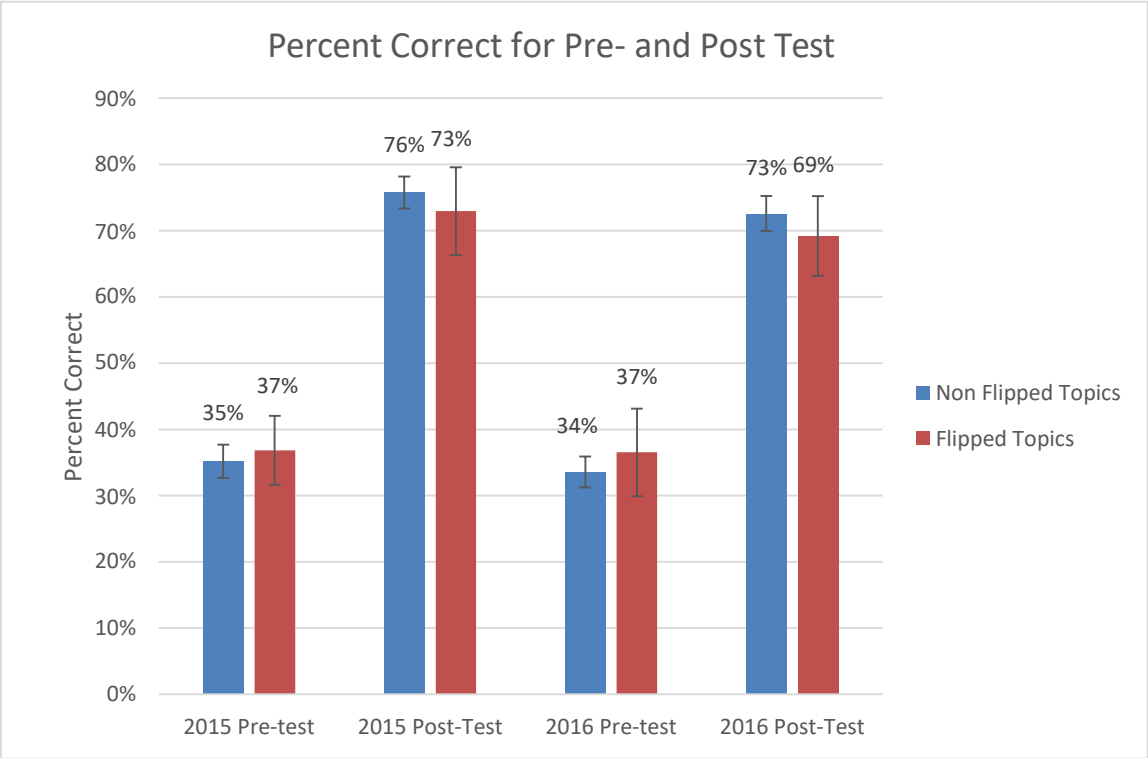


Figure 2. Average percent correct on pre-and post-test for flipped and non-flipped topics for control (2015) and intervention (2016) semesters.

The Fall 2015 control year and the Fall 2016 intervention year had pre-test percent correct averages on non-flipped topic test items that were very similar. 2015 pre-test non-flipped topics were showed 35% correct responses and 2016 pre-test non-flipped topics were showed 34% correct responses. Flipped topic test items on the 2015 pre-test were showed at 37% correct responses that had an identical average to the 2016 pre-test flipped topic test items also at 37% correct responses.

Percent correct averages from the pre-test to the post-test increased, as expected, in both 2015 and 2016. There was a main effect for test, $F(1, 292) = 1114.02$, $p < .001$ (p-values less than 0.05 indicating significance), indicating that there were significant

differences between pre- and post-test scores, regardless of year. This was expected because scores improved drastically in both flipped and control groups from pre-test to post-test. Figure 2 shows the percent change on both control and flipped questions from pre- to post-test in 2015 and 2016. Flipped topics in 2015 increased from 37% correct responses on the pre-test to 73% correct responses on the post-test and non-flipped topics increased from 35% correct responses on the pre-test to 73% correct responses on the post-test. Although both the control year and intervention year saw expected increases from pre-test to post-test scores, flipped topics and non-flipped topics did not increase the same in both the 2015 and 2016 fall semesters as shown in Figure 3.

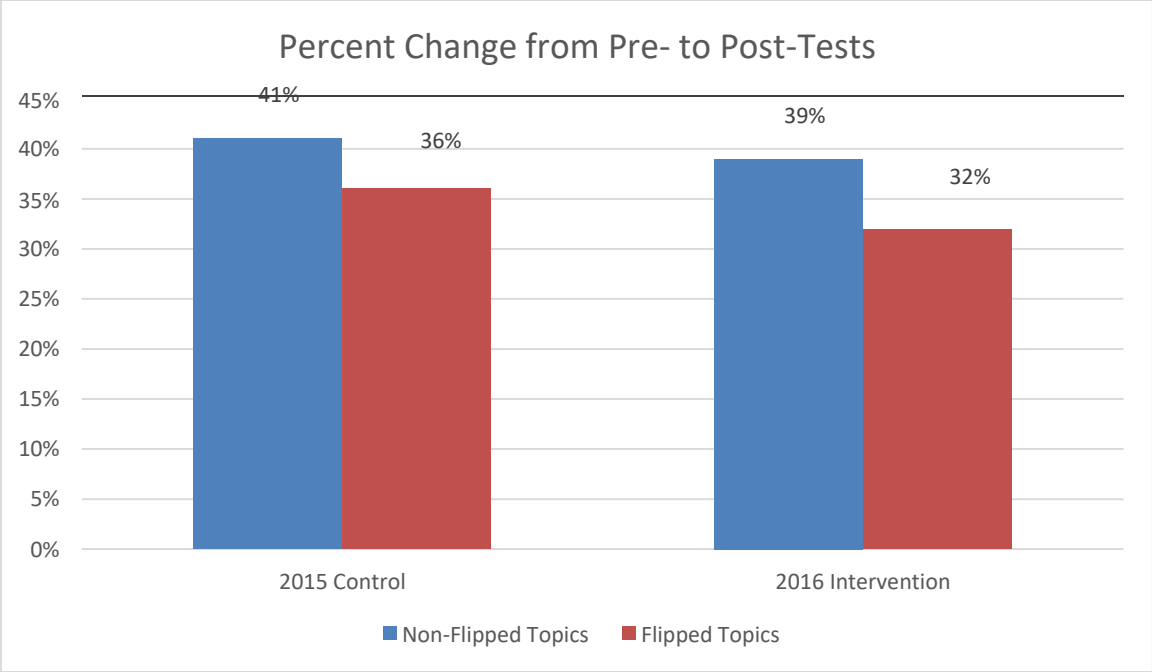


Figure 3. Percent change from pre- to post-test in control (2015) and intervention (2016) semesters.

Individual student data. To support preliminary item analysis data of overall participant averages, tests were conducted using individual student data. Individual student data was entered into a Microsoft Excel spreadsheet for each question on both pre- and post-tests. Students were de-identified and each participant was assigned a unique identification number. An input of 1 indicated a correct response to a test item and an input of 0 indicated an incorrect response. This data was then transferred to SPSS statistics software.

Individual student data supports the item analysis data because the same averages were found for flipped topic questions when percent correct averages were calculated. Table 6 shows the individual student data for flipped topics on the pre-test and post-tests in both 2015 and 2016. Highlighted are the identical average percent correct for flipped test items in both 2015 and 2016 as seen in Figure 2 from the test item analysis data.

Table 6

Individual student data percent correct averages for flipped and non-flipped topics

Year		Mean	Std. Deviation	*N*
Pre-Test flipped	2015	37.96	17.437	133
topics item total	2016	37.41	16.306	147
Post-Test flipped	2015	73.01	17.537	133
topics item total	2016	69.46	16.912	147

A paired *t*-test was done to evaluate the change from pre-test to post-test in the 2015 control year and the 2016 intervention year. Results showed that again there was a highly significant difference ($p < 0.001$) from pre- to post-test scores in both years as expected (see Table 6).

Intervention Year- Performance on Flipped Topics v. Non-flipped Topics (Control) in 2016

ANOVA results comparing pre- to post-test changes among questions marked as control and questions marked flipped showed that although participants improved on both control questions and flipped questions in the 2016 intervention year, there was a significant interaction effect. This indicates that participants increased at a significantly higher magnitude on control questions than flipped questions, $F(1, 292) = 9.89$, $p = .002$.

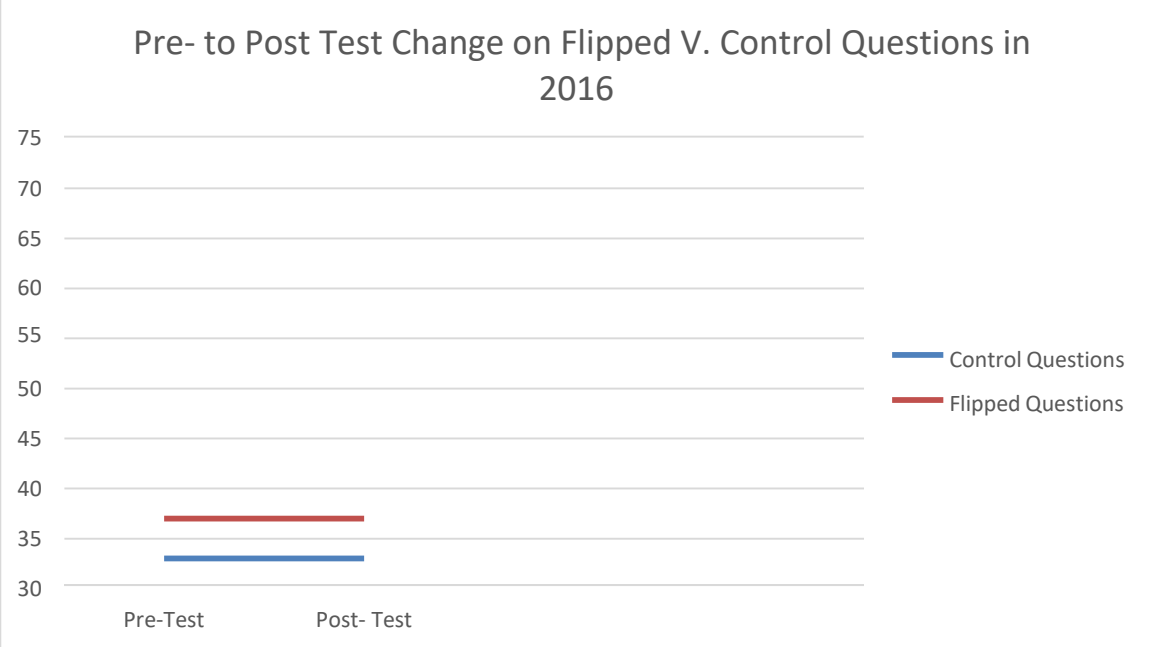


Figure 4. Pre-to Post Test Change on Flipped v. Control Questions in 2016.

The graph in Figure 4 shows the interaction effect. Had the lines been parallel, there would not have been an interaction effect. The effect size was calculated using the Cohen's D formula, with an effect size of 0.2 showing a small effect, 0.5 representing a moderate effect and 0.8 or higher representing a large effect. When effect size from pre-test to post-test was calculated for the 2016 intervention semester, the effect size was large for both flipped topic questions (1.93) and non-flipped topic questions (3.10). This shows from pre-test to post-test scores increased a large degree on both flipped and control topics. However, flipped topics did not increase the same as control topics indicated by the non-parallel lines shown in Figure 4. The effect seems to be small based on the figure. The η^2 effect size (eta square) included in the output above also indicated a small effect ($\eta^2 = .03$).

"Flipped Topics"- Topics Taught Traditional Method 2015 control v. Flipped 2016 Intervention (10 test items)

Independent *t*-test results comparing 2015 to 2016 on the 10 post-test flipped questions indicated that the final score on flipped questions was not a statistically significant difference between the two years $t(278) = 1.72$, $p = .09$. ANOVA results showed that regardless of year, students improved overall on test items from pre- to post test. It also showed no interaction effect meaning there was no difference ($F1\ (278) = 1.347$, $p = 0.247$) in how students improved on the 10 flipped topic questions between 2015, taught in traditional lecture style, and 2016 taught using the flipped method. Figure 5 illustrates the change in mean from pre- to post-test flipped test questions for both the

control year of 2015 and the intervention year of 2016. Nearly parallel lines indicate no interaction effect between the two years.

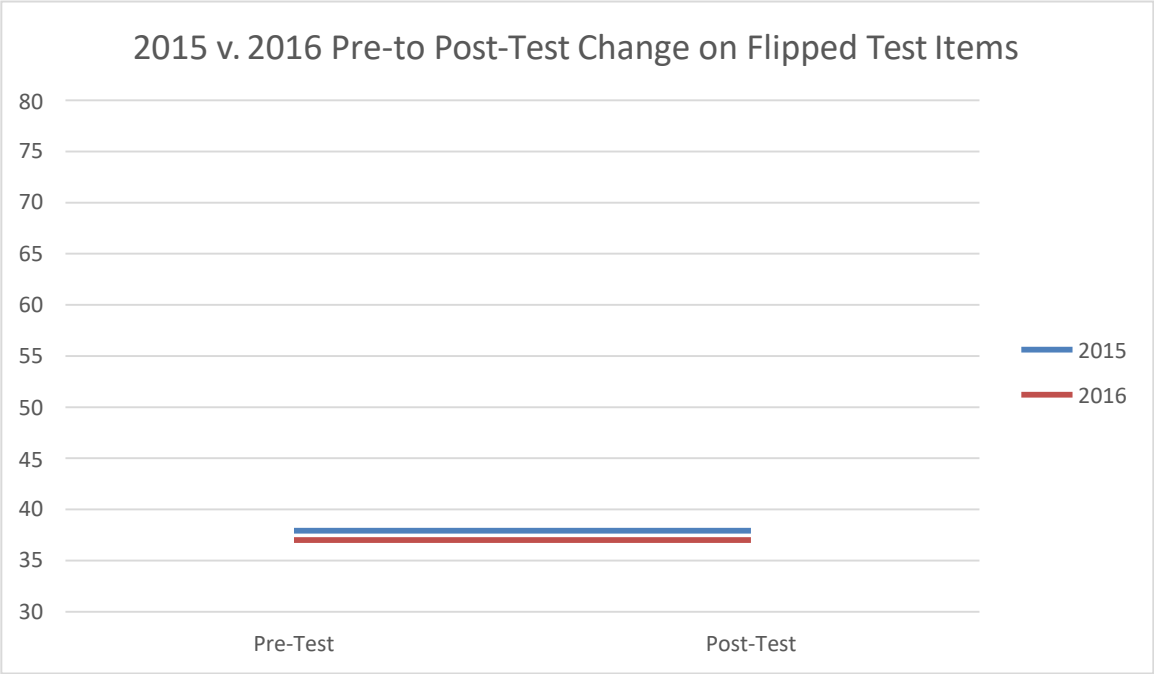


Figure 5. 2015 v. 2016 Pre- to Post- Test Change on Flipped Test Items.

"Non-flipped Topics"- Topics Taught Traditionally in Both 2015 and 2016 (40 test items)

Independent *t*-test results indicated there was no significant difference ($t(278) = 1.825$, $p = 0.069$) on how participants performed from pre- to post-test on the 40 test questions marked control and taught traditionally in both 2015 and 2016. ANOVA results for control questions between the 2015 and 2016 year for control questions supported these results ($F1(278) = 0.259$, $p = 0.611$) indicating there was no interaction effect and

the years did not differ on how they improved. Figure 6 below illustrates the change in mean from pre- to post-test 40 control test questions for both the control year of 2015 and the intervention year of 2016.

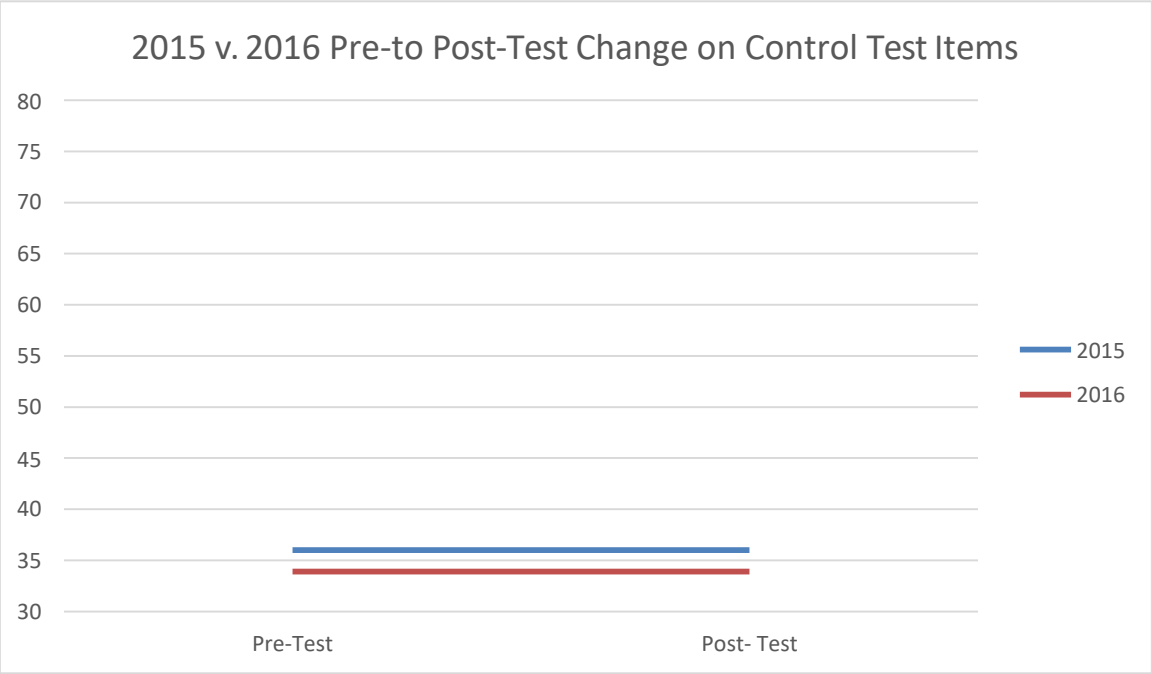


Figure 6. 2015 v. 2016 Pre-to Post-test Change on Control Test Items.

Analysis to Address Hypothesis 2

Students performing in the bottom third on the pre-test would improve more than students in the top third on the flipped topic questions than on the non-flipped topic questions from pre-test to post-test.

After the overall class performance and individual performance of participants were evaluated for changes from pre- to post-test scores, participants were then grouped

into low, middle, and high achieving groups based on their pre-test scores. A scale of 0-1 was used to indicate pre-test performance with a 0 indicating no questions correct, and a 1 indicating answering all 50 questions correct. Pre-test scores were divided as follows: a score of 0-0.3 were marked as a 1 or low, scores of 0.301-0.38 were marked as 2 or middle, and scores of 0.3801 or higher were 3 or high achievers. Group 1 (low achieving) scored between 0-0.3, group 2 (middle achieving) scored between 0.301- 0.38, and group 3 (high achieving) scored between 0.4-0.64 (0.64 being the highest score received by a participant).

Low, Middle, and High Achieving Participant Performance on Flipped Topics in 2016

Table 7 shows results when averages for the 10 flipped topic questions were calculated for Groups 1, 2, and 3 on both the pre-test and post-test in the 2016 intervention year.

Table 7

Flipped Topic Question Averages on Pre- and Post-Test for Groups 1, 2, and 3 in the 2016 Intervention Year

10 Flipped topic Questions scores		Mean	Std. Deviation	N
Pre-test scores	Group 1-low	27.64	14.778	55
	Group 2-mid	36.53	12.341	49
	Group 3-high	50.93	12.500	43
	Total	37.41	16.306	147
Post-test scores	Group 1-low	63.64	17.885	55
	Group 2-mid	70.20	16.645	49
	Group 3-high	76.05	13.299	43
	Total	69.46	16.912	147

An ANOVA was conducted to analyze the difference in pre- to post-test scores for the low, middle, and high-achieving participants on the 10 flipped topic questions. The results indicated that the groups differed on the magnitude of change they experienced. The low achievers increased at a significantly higher magnitude compared to the high achievers, $F1(144) = 3.429$, $p = 0.035$. Figure 7 illustrates the data from Table 7.

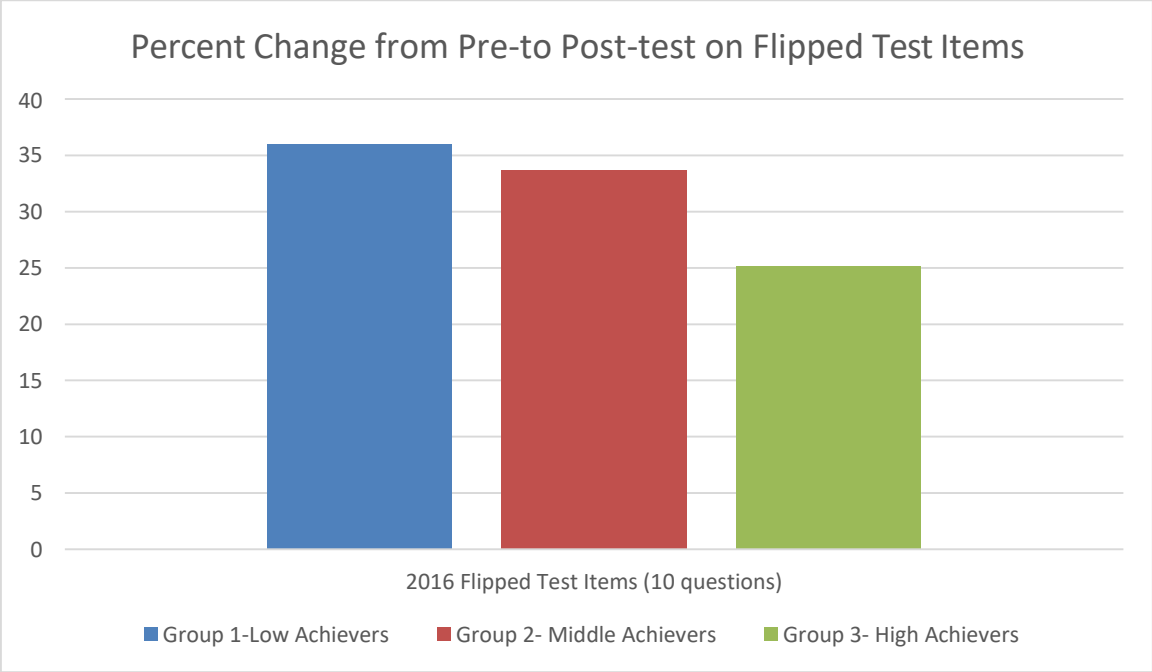


Figure 7. Group 1, 2, and 3 Percent Change from Pre-test to Post-Test on Flipped Test Items.

Low Achieving Participants- 2015(traditional) v. 2016(flipped)

Once results were analyzed for comparing low, middle and high achieving students in the intervention year, an ANOVA was conducted to determine if there was a

difference in how low achieving group 1 participants performed on the 10 flipped topic questions when taught these topics using traditional method in 2015 versus the flipped model in 2016. Results indicated that there was no significant difference in how participants in 2015 improved in comparison to the participants in 2016, $F1(95) = 2.226$, $p = 0.139$. However, Figure 8 shows that although there was no statistically significant interaction and the groups increased at roughly the same magnitude, participants in the 2015 control year started out with lower pre-test scores and finished with higher post-test scores when taught traditionally compared to the 2016 intervention year in which these topics were taught using the flipped method.

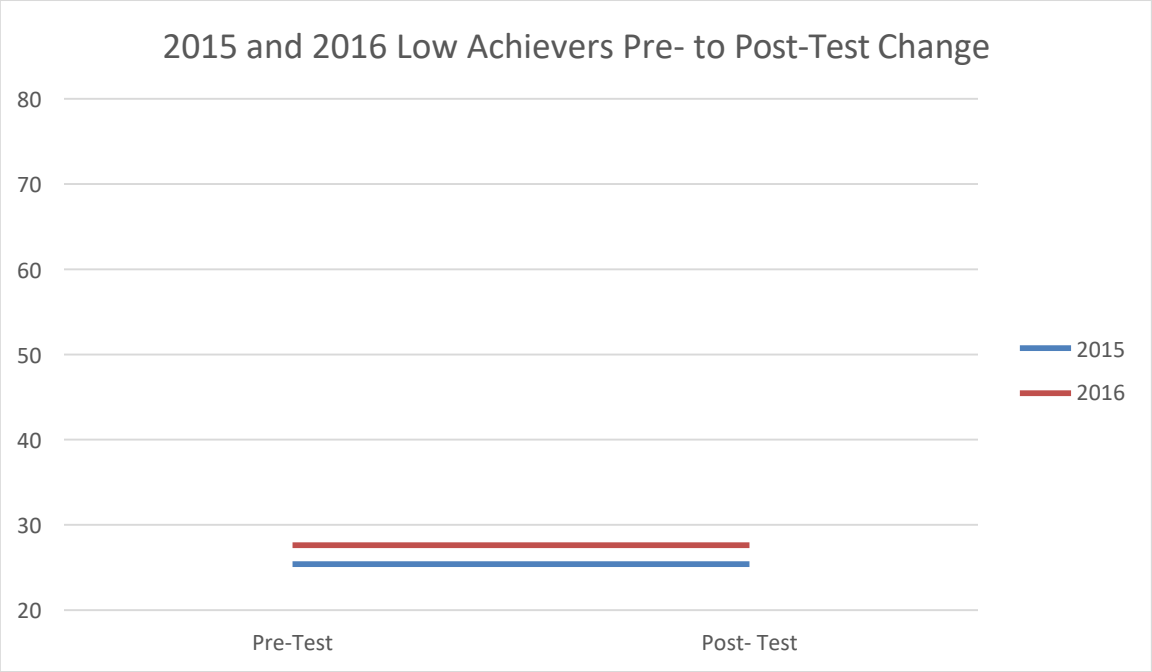


Figure 8. 2015 and 2016 Low Achievers Pre- to Post-Test Change on Flipped Test Items.

CHAPTER IV

DISCUSSION AND CONCLUSION

As expected, results indicate that participants, regardless of year, topic, or method improved from pre-test to post-test. This was expected because they all received knowledge over the tested material throughout the semester. The researcher's questions related to if participants performed better when taught using the flipped instruction method as opposed to a traditional lecture method.

In regards to **Hypothesis 1, academic performance would increase more on test items taught using the flipped classroom approach than on test items taught using traditional lecture methods,** results did not support this hypothesis in any of the tests or comparisons. Participants in the intervention year actually improved more on topics taught traditionally than topics taught using the flipped method. Also, when the intervention year was compared to the control year, there was no significant difference in how participants performed on test items when taught Chapters 6 and 12 regardless of teaching method. Although there was no improvement when participants were taught using the flipped model, it is important to note that there was also not a significant decrease in performance of participants when taught using the flipped model. This is valuable to educators who are considering using this method.

In regards to **Hypothesis 2, students performing in the bottom third on the pre-test would improve more than students in the top third on the flipped topic questions than on the non-flipped topic questions from pre-test to post-test,** results

supported this hypothesis. Participants in Group 1 marked low achievers did improve more from pre-test to post-test on topics taught using the flipped model. However, in the 2015 control year when these same topics were taught using traditional lecture, students also improved at the same rate as when taught using the flipped model. Therefore, more research is needed in this area to determine if low achieving students actually do benefit more from this model.

Unexpected results showed that participants scored lower on their pre-test flipped topics than control topics regardless of year as shown in Figure 2. They started out lower and finished lower on these test items than on control items. This could indicate that these topics might be more difficult or further investigation into the quality of the questions might be needed.

Other factors that could have affected results are that in this study only two topics were taught using the flipped model for the intervention semester. As the saying goes, "practice makes perfect." Most studies referenced were designed where the intervention semester was fully flipped and all topics were taught using the model. Participants in this study may not have seen significant gains on the flipped topics because they were not as familiar with the method. Future studies might address how performance is affected by the amount of topics taught using the flipped model and if there are greater academic improvements as students get more accustomed to the model.

In conclusion, the flipped classroom model appears to not decrease academic performance, which is good news. If educators can rely on their students still obtaining the same base content either using traditional lecture or flipping, then why go through the effort to change your method at all? The answer could be increased engagement of

students. As noted in the study with Butt (2014), students feel they learn best through performing an activity as opposed to reading or listening to lecture. The flipped model allows educators to free up class time to perform hands-on, engaging, real world, or critical thinking activities without having to sacrifice content knowledge time. If class time is just used to do homework then results are not showing greater improvement using this model (Ryan & Reid, 2015; Butt, 2014; Shultz et al., 2014; Munson & Pierce, 2015; Findlay-Thompson & Mombourquette, 2014). If considering the flipped model for a classroom, it is suggested that educators take advantage of all the model has to offer. The advantages to this model may lie in what is happening in class. Can the new abundance of class time be used to improve other skills? While some might view flipping as just taking lecture out of the class and doing it at home, research has shown this does not affect performance. Now, future research should focus on how this model allows educators to add value to their students in other ways by effectively incorporating in-class activities. It should be noted that this study measured changes in content knowledge, not critical thinking. Future studies could focus on measuring other gains made by students.

REFERENCES

Bergmann, J. & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day.* Alexandria, VA: The International Society for Technology in Education and Association for Supervision and Curriculum Development. 112p.

Bishop, J. & Verleger, M. (2013). The flipped classroom: A survey of the research, 120th ASEE Annual Conference and Exposition, Atlanta, GA, June 23-26, 2013. Atlanta, GA, American Society for Engineering Education.

Butt, A. (2014). Student views on the use of a flipped classroom approach: Evidence from Australia. *Business Education and Accreditation,* 6(1), 33-43. Retrieved from: www.theibfr./bea.htmcom http://theibfr.com/ARCHIVE/BEA-V6N1-2014-revised.pdf.

Findlay-Thompson, S. & Mombourquette, P. (2014). Evaluation of a flipped classroom in an undergraduate business course. *Business Education and Accreditation,* 6(1), 63-71. Retrieved from: www.theibfr./bea.htmco http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2331035.

Foldnes, N. (2016). The flipped classroom and cooperative learning: evidence from a randomised experiment. *Active Learning in Higher Education,* 17(1), 39-49. doi: 10.1177/1469787415616726.

Gilboy, M & Heinerichs, S. & Pazzaglia, G. (2015). Enhancing student engagement using the flipped classroom. *Journal of Nutrition Education and Behavior,* 47(1), 109-114. doi: 10.1016/jneb.2014.08.008

Gorres-Martens, B. & Segovia, A. & Pfefer, M. (2016). Positive outcomes increase over time with the implementation of a semi-flipped teaching model. *Advances in Physiology Education*, 40(1), 32-37.

Herried, C & Schiller, N. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching,* 42(5), 62-66. Retrieved from: http://sciencecases.lib.buggalo.edu/cs/pdfs/Cases_Flipped_Classroom.pdf.

Hudson, T. (2015, July). Little girl lost: A case study on defective cellular organelles. Retrieved from: http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=783&id=783.

Love, B., Hodge, A., Grandgenett, N., Swift, A. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology*, 45(3), 317-324. Retrieved from: http://dx.doi.org/10.1080/0020739X.2013.822582.

Marsh, M. (2016, February). Who killed yew? Murder and mitosis. Retrieved from: http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=820&id=820K

Michaelsen, L.K. & Sweet, M. (2011). Team-based learning. New directions for teaching and learning. *Winter 2011*, (128), 41-51.

Munson, A. & Pierce, R. (2015). Flipping content to improve student examination performance in a pharmacogenomics course. *American Journal of Pharmaceutical Education*, 79(7), 1-7. doi: 10.5688/ajpe797103.

O'Flaherty, J. & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education,* 25, 85-95. doi: 10.1016/j.iheduc.2015.02.002

Peterson, D. (2016). The flipped classroom improves student achievement and course satisfaction in a statistics course: A quasi-experimental study. *Teaching of Psychology*, 43(1), 10-15. doi: 10.1177/0098628315620063

Ryan, M. & Reid, S. (2016). Impact of the flipped classroom on student performance and retention: A parallel controlled study in general chemistry. *Journal of Chemical Education,* 93(1), 13-23. doi: 10.1021/acs.jchemed.5b00717

Schultz, D., Duffield, S., Rusmussen, S., Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education,* 91(9), 1334-1339. doi: 10.1021/ed400868x

Shukr, I., Qamar, K., Hassan, A. (2016). Faculty's perceptions of level of teacher's motivation. *Pak Armed Forces Med J,* 66(6), 784-89. Retrieved at: http://www.pafmj.org/art_pdf/2-3288-%20Khadija%20Qamar.pdf.

Talley, C. & Scherer, S. (2013). The enhanced flipped classroom: Increasing academic performance with student-recorded lectures and practice testing in a "flipped" STEM course. *The Journal of Negro Education,* 82(3), 339-347. doi: 10.7709/jnegroeducation.82.3.0339.

Wallender, J. (2014). The common core state standards in American public education: Historical underpinnings and justifications. *Impact of Educational Reforms, 1*, 7-11. Retrieved at: https://www.questia.com/library/journal/1P3-3399899301/the-common-core-state-standards-in-american-public.

APPENDIX A

10 Flipped Topic Test Questions

10 Flipped topic test questions

Flipped topic 1 (Chapter 6, Unit 2, the cell)

Which type of organelle is primarily involved in the synthesis of oils, phospholipids, and steroids?

A. Smooth endoplasmic reticulum
B. Mitochondrion
C. Contractile vacuole
D. Ribosome
E. Lysosome

Which of the following contains its own DNA and ribosome?

A. Peroxisome
B. Vacuole
C. Mitochondrion
D. Golgi bodies
E. Lysosome

Which of the following are capable of converting light energy to chemical energy?

A. Leucoplasts

B. Mitochondria

C. Chloroplasts

D. Golgi bodies

E. Peroxisomes

A cell has the following molecules and structures: enzymes, DNA, ribosomes, plasma membrane, and mitochondria. It could be a cell from

A. A plant or animal

B. A bacterium

C. An animal, but not a plant

D. A plant, but not an animal

E. Any kind of organism

Which structure is common to plant and animal cells?

A. Wall made of cellulose

B. Mitochondrion

C. Central vacuole

D. Centriole

E. Chloroplast

Which structure-function pair is mismatched?

A. Ribosome; protein synthesis

B. Lysosome; intracellular digestion

C. Microtubule; muscle contraction

D. Nucleolus; production of ribosomal subunits

E. Golgi; protein trafficking

Flipped topic 2 (Chapter 12, Unit 3, mitosis)

Cytokinesis usually, but not always, follows mitosis. If a cell completed mitosis but not cytokinesis, the results would be a cell with

A. High concentrations of actin and myosin

B. Two abnormally small nuclei

C. Two nuclei

D. A single large nucleus

E. Two nuclei but with half the amount of DNA

The somatic cells derived from a single-celled zygote divide by which process?

A. Mitosis

B. Replication

C. Binary fission

D. Cytokinesis alone

E. Meiosis

Imagine looking through a microscope at a squashed onion root tip. The chromosomes of many of the cells are plainly visible. In some cells, replicated chromosomes are aligned along the center (equator) of the cell. These particular cells are in which stage of mitosis?

A. Prometaphase
B. Telophase
C. Anaphase
D. Metaphase
E. Prophase

DNA is replicated (copied) at this time of the cell cycle:

A. G_0
B. G_2
C. G_1
D. M
E. S