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IMPLEMENTATION OF A FLIPPED CLASSROOM IN A NON-MAJORS' BIOLOGY COURSE

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IMPLEMENTATION OF A FLIPPED CLASSROOM IN A NON-MAJORS' BIOLOGY COURSE

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ABSTRACT

Changes to teaching practices have been requested in almost every field of science and mathematics but their implementation can be daunting. The flipped classroom has become a popular method in K-16 education for integrating active learning in the classroom. Research on the implementation of flipped classrooms has been met with mixed results, however. I sought to determine the effectiveness of the flipped classroom while addressing methodological needs cited by past studies including: using both faculty and student demographic variables, addressing assessment performance using concept inventories, and studying faculty who are not trained in pedagogy. I found that flipped and non-flipped faculty self-reported approaching teaching in a similar way and when reviewed by external reviewers, little difference was seen between groups. Flipping the classroom was associated with negative changes in attitudes towards the need for science. There was no meaningful difference in learning gains in flipped and non-flipped classes. I suggest that effective implementation of active learning in a flipped classroom requires that faculty are trained in the use of active learning practices and modern pedagogy.

LIST OF FIGURES

CHAPTER 1

LITERATURE REVIEW

INTRODUCTION

"The time has come for all biology faculty, particularly those that teach undergrads, to develop a coordinated and sustainable plan for implementing sound principles of teaching and learning to improve the quality of undergraduate biology education nationwide"(AAAS, 2009). In 2009, the National Science Foundation (NSF) and the American Association for the Advancement of Science (AAAS) hosted an invitational conference for over 500 biology faculty, college and university administrators, professional society representatives, and students from around the country. This convention was named Vision and Change in Undergraduate Biology Education and sought to look at how biology education could be improved. The quest for improvement could not have come at a more urgent time. The United States is in need of 1 million more STEM graduates than is being produced which would require an annual increase in STEM graduates of 34% in the next decade to fill the deficit (Olson and Riordan, 2012). The need for a strong science background, not just for STEM graduates, but for all students, is an urgent one that is recognized by several associations including The National Science Foundation and the Office of the President (AAAS, 2009; AAAS and NSF, 2012; Olson and Riordan, 2012). The need for change has been recognized, but how to achieve it has been debated among faculty, administrators and education researchers (AAAS, 2009; Andrews *et al.,* 2011; Burgan, 2006; Prince, 2004). Among the topics discussed at the Vision and Change Conference was the need for innovative and evidence-based pedagogy. Recommendations that resulted from the conference called for more learner-centered teaching in undergraduate courses, particularly introductory-level courses.

Learner-centered teaching involves engaging students by having them actively participate in the learning process. There is a preponderance of evidence in the primary literature showing learner-centered teaching is more beneficial to students than traditional lecture ("Active Learning in the College Classroom," 2014; Freeman *et al.*, 2014; Froyd, 2007; Jensen *et al.*, 2015; Prince, 2004). A meta-analysis of 225 studies shows when learner-centered teaching was implemented in STEM classes, it was associated with increased scores on examinations and concept inventories (Freeman *et al.*, 2014). Improvements in learning require that faculty transform their teaching from teacher-centered to learner-centered. There are many active-learning pedagogies available for instructors to use in higher education classrooms that can move classrooms towards a learner-centered environment. Some examples include collaborative and small group learning, inquiry-based learning, challenge-based learning, peer-led team learning, and many more (Froyd, 2007).

The "flipped classroom" is another pedagogical method that takes an active, learner-centered approach to teaching. Students gain first-exposure to course material prior to class through videos or readings and then focus on the processing part of learning, such as analyzing and synthesizing information, in class (Brame and Director, 2013). The flipped-classroom approach to learner-centered teaching has been associated with increased student performance and improved student attitudes (Pierce and Fox, 2012). By allowing students to express their factual knowledge and receive real time feedback from their peers and faculty, students' misconceptions can be corrected sooner which leads to a deeper understanding of concepts being studied (Brame and Director, 2013). A number of researchers examined the use of flipped classrooms as a viable option for learner-centered teaching and obtained varied results (Bishop and Verleger, 2013). Some results indicated that the flipped-classroom model increased student learning gains and improved attitudes (Feledichuk and Wong, n.d.; Galway *et al.*, 2014) while others found that students in flipped-classrooms were discouraged by the amount of work asked of them (Bishop and Verleger, 2013). I propose to investigate the influence of varying degrees of learner-centered teaching, from traditional lecture to a flipped classroom, on students' attitudes towards science, science literacy, and learning gains. Throughout my research I define the flipped classroom model as a classroom where the professor provides lecture material outside of class and engages the students in active learning activities during class time.

BACKGROUND

Status of American Education and the Call for Reform

Since America lost the race to space to the Russians after they released Sputnik, there has been a call for reform on the education that Americans receive (Atkin, 1997). The call for reform stretches not only from kindergarten to graduate school, but also across the decades since the beeping of Sputnik was heard around the world. In the spring of 1983, the National Commission for Excellence in Education put together by the Reagan administration released *A Nation at Risk* (1983) which was a report to the American people addressing the many problems our country was facing, and about to face due to a lack of rigor and accountability in our educational system. *A Nation at Risk* was centered around four major topics that included a need for more rigorous content, higher expectations of students, longer school days, and improvement of teacher quality

(Gardner, 1983). How we can improve the education of our citizens is a question that has been asked during each decade since publication of "A Nation at Risk".

In the 1990's, we saw great strides in education reform on the state level. States began shifting their focus on the educational output of students (i.e., scores on assessments) instead of the educational inputs per student (i.e., cost of instructional materials; Hurst *et al.*, 2003). The majority of legislation that occurred in the 1990's focused on academic standards, which was a key component of the "A Nation at Risk" recommendations. Efforts to raise state academic standards focused on improving content standards, performance standards (how well students must do to be considered proficient), accountability systems (for schools and school districts), and assessments to measure change in students' knowledge and skills (Hurst *et al.*, 2003)The shift of education reform on the state level led to most states adopting one or more of these components by the end of the decade. For example, the number of states that instilled newly developed mathematics standards increased from 25 to 49 and the number of states having science standards increased from 23 to 49 (Hurst *et al.*, 2003). Improved standards were a starting point for America in its ambition to once again become a leader in the scientific community of the world. The passing of the Goals 2000: Educate America Act of 1994, signed by President Clinton, was a continuation of this ambitious endeavor. The Act called for the U.S. to be first in the world in science and mathematics achievement (US Congress, 1994).

In 2009, AAAS and NSF hosted a conference named Vision and Change, that was attended by over 500 invited faculty, administrators, and representatives from scientific professional organizations; all of whom were in some way engaged in reform in STEM education. The mission of the conference was to identify and agree upon core concepts and competencies that biology students need to master before graduating with an undergraduate degree. These competencies and concepts were meant to be an adaptable starting point based on the collaborative experience and wisdom of the broad national community of scientists, biologists, and educators (AAAS, 2009).

In 2012, the Obama Administration released a report entitled Engage to Excel (Olson and Riordan, 2012),which has become one of the leading documents on the status of STEM higher education to date. The report details the need for an additional 1 million STEM graduates to fill the projected needs of the workforce, along with calls to improve the first two years of STEM education at the collegiate level, diversify the pathways that lead to STEM degrees, and provide all students with the tools that they need to excel(Olson and Riordan, 2012).

What did we learn from Vision and Change and Engaged to Excel?

The field of Biology itself is undergoing a change with increasing discoveries at intersecting disciplines which led to an emergence of interdisciplinary fields such as systems biology, genomics, and synthetic biology, to name a few. Future scientists need to be able to think beyond their own disciplines, work with large data sets, and keep up with change in technology. These demands on today's and future scientists provide a challenge for faculty who must work with students who have a broad range of socioeconomic and academic backgrounds. What came out of the Vision and Change conference were five core concepts and six competencies that all undergraduate students need to master in biology. The participants agreed that all students need to have a basic understanding of evolution, structure and function, information flow and exchange, pathways and transformation of energy and matter, and living systems (AAAS, 2009). These five subjects make up the core concepts or backbone that are recommended as a basis for all university curricula in biology. Although knowledge and understanding of these concepts is important, there are also skills and competencies all students need to obtain while earning their undergraduate biology degree.

Students must have the ability to process scientific information and understand that science is evidence-based. Students need to be able to use quantitative reasoning because biology relies on quantitative applications and mathematical reasoning. Biology undergraduates also need to be able to use modeling and simulations because the biological sciences are vast and complex. Along with these abilities, students must be able to utilize the interdisciplinary nature of science and apply concepts and make connections among disciplines. Biology is a collaborative science so students must have the ability to communicate and collaborate, not only with peers in their field but also across multiple disciplines. Lastly, students need to graduate with the understanding that biology is conducted in a social context and that biologists have an obligation to help society understand and solve critical issues. These five concepts and six competencies allow students to be more successful as biologists because they not only have the knowledge they need but also have the skills and abilities demanded by the workforce.

The President's Advisors on Science and Technology's Report: Engaged to Excel 2012, details the need for an additional 1 million STEM graduates to fill the projected needs of the workforce. Currently, approximately 40% of students who enter college with the intention of receiving a degree in a STEM field actually do by the time that they graduate. Even though women and minorities make up 70% of all college students, they currently comprise only 45% of students who graduate with a STEM degree (Olson and Riordan, 2012). Efforts must be made to increase student interest within STEM fields and retention of STEM students if we are to answer the call for a dramatic increase in STEM graduates Reasons students give for leaving STEM programs include a lack of engagement and difficulty with the math required in introductory level classes (Olson and Riordan, 2012). If universities across the nation could address these problems and increase interest and retention rates by only 10% for STEM degree-seeking students, then three-fourths of the 1 million called for would be obtained. The question remains on how to achieve the increase in retention.

How do we Implement Strategies to Address what we Learned?

To address the need for an additional 1 million STEM graduates, we need to understand not only who chooses a STEM major when beginning a college career but also why STEM majors choose to abandon their studies in STEM disciplines. Based on the 1996-2001 Beginning Postsecondary Students Longitudinal Study (BPS:96/01), a total of 23% of beginning post-secondary students entered STEM majors at some point during their enrollment, with a higher percentage in biology/agricultural sciences, engineering and computer technology than in mathematics and physics (Chen, 2009). There was a higher percentage of men than women entering the STEM fields (33 % vs 14 %). Almost half of Asian/Pacific Islander students (47%) entered STEM fields compared with all other races (19-23%; (Chen, 2009). Students who were younger (19 or younger), from a foreign country, had a family income in the top 25% of the country, or who had parents with some college education were all more likely to enter STEM fields (Chen, 2009).

Now that we have an understanding of the demographics on students who enter STEM majors, we can look at why they choose to leave. Seymour and Hewitt (1997) found three main reasons that undergraduates give for leaving the sciences. These were loss of interest in the sciences, growing interest in another major, and poor teaching. Science attrition has usually occurred within the first two years of an undergraduate's study. Thus, focusing on better teaching practices in introductory level courses, which are usually taken in the first two years of study, is of great importance to increasing retention rates (Olson and Riordan, 2012; Seymour *et al.*, 1997). Seymour and Hewitt also found that students do not feel prepared for courses in STEM majors; but even well-prepared students leave saying that there was poor teaching, professors cared more about their research than teaching, and that the curriculum lacked structure (Seymour *et al.*, 1997). These results suggest that reforms in STEM higher education must not only focus on teaching practice, but also on a system that rewards faculty for their teaching accomplishments to the same extent as their research accomplishments (Brownell and Tanner, 2012).

It is clear from the outcomes of the Vision and Change conference that undergraduate STEM programs, in particular biology programs, need to establish introductory curricula that include rigorous standards and address the key concepts and competencies discussed earlier. Brownell *et al.* (2014) facilitated use of the competencies by publishing the Vision and Change Biocore guide, which provides a framework that biology departments can use to align their goals with those from Vision and Change. In order to develop a tool that biology faculty would use, the Biocore built the guide from the ground up, starting first with biology faculty and including them in every step of the process. A ground-up process is unusual in that the majority of studies conducted in curriculum reform start with education researchers and then work their way down to discipline-specific professionals (Brownell *et al.*, 2014). The development of the Biocore guide consisted of 2 phases. In Phase I, faculty of the University of Washington surveyed the concepts set forth by Vision and Change and then agreed upon 2-3 statements per concept per sub-discipline. Phase II of development consisted of iteratively modifying these statements nationally, then nationally validating the statements and principles by biology educators and biologists. The final guide spans a 4-year curriculum for colleges and universities to use nationwide. Determining a structured curriculum that is agreed upon by biological faculty nationwide is the backbone of reform; but the implementation of how we teach these concepts and skills is critically important.

Evidence-Based Teaching

According to Bruce Alberts (National Research Council, 1997), the President of the National Academy of Sciences (1993-2005), "Research has taught us a great deal about effective teaching and learning in recent years, and scientists should be no more willing to fly blind in their teaching than they are in their in their scientific research." Lecturing has been the dominant teaching method used in classrooms for over 900 years (Brockliss, 1996). As our knowledge of learning increases, however, there is also an increase in evidence that traditional lecturing is not the most effective way to teach given today's students and higher education system (i.e., mass education). Extensive evidence documents that using a more learner-centered and active-learning approach to teaching increases student performance. Ming-Zher Poh et al. (2010) studied 26 participants who wore an unobtrusive sensor that measured electro dermal activity which was correlated with brain activity during their daily lives. A dramatic drop in brain activity occurred when students were attending class (lecture), measuring lower than every other activity including sleep (Fig 1).

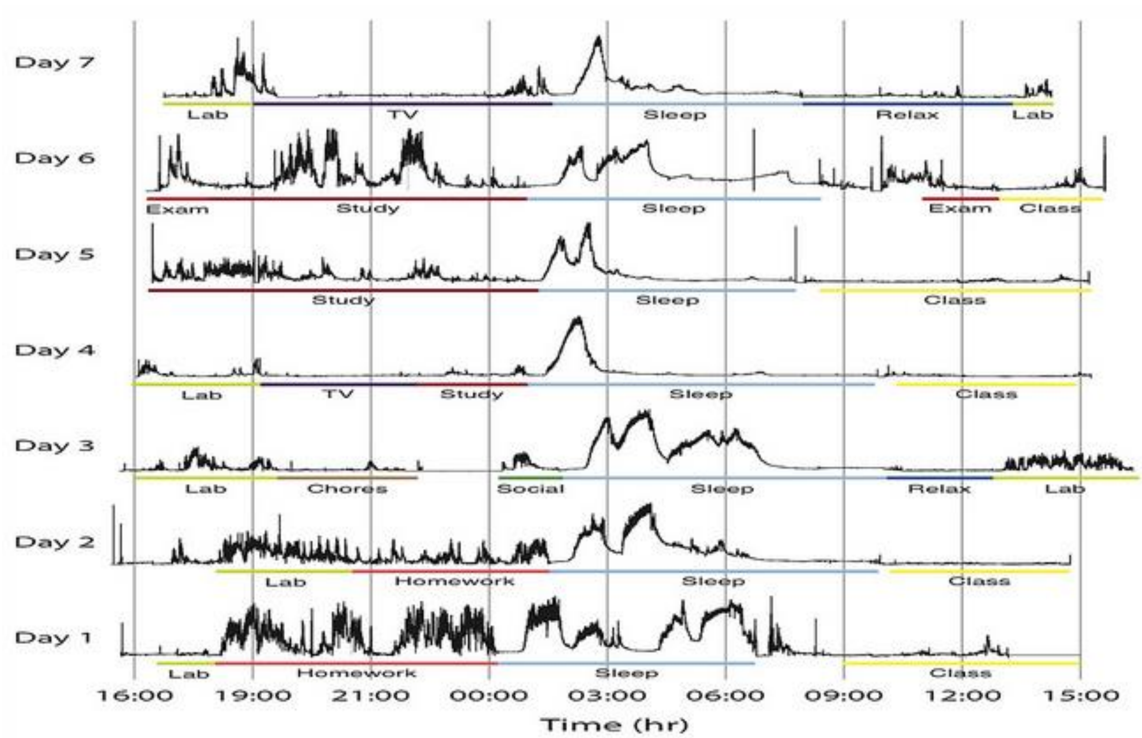

Fig. 1 Ming-Zher Pong *et al.* (2010) Long-term *in situ* EDA recordings. Continuous skin conductance measurements were recorded for seven days in a natural home environment. Daily EDA waveforms displayed are normalized.

Knight and Wood (2005) compared the learning gains (pre/post-tests) of students in a traditional developmental biology lecture classroom with a more interactive classroom and found that students in the interactive classroom had significantly larger learning gains. Freeman *et al.* (2014) conducted a meta-analysis of 225 studies that reported examination scores and failure rates of students in active learning or traditional lecture classes. In classes where some active learning was present, student performance on exams was higher compared to lecture classes. In contrast, lecture-based classes were associated with a failure rate that was 55% greater than in active-learning classes across all STEM disciplines regardless of class size, course type, or level.

There are many different activities and teaching methods that are considered to be learner-centered and that can be adapted by faculty to fit their needs (Froyd, 2007). Methods of learner-centered teaching include practices that are inquiry-driven, cooperative, collaborative, and above all relevant (AAAS, 2009). The following teaching practices are effective learner-centered approaches that have been used in STEM higher education.

Experiential Learning

One of the larger debates in education is the importance of skill-based and content-based education. This debate has created widespread research on different pedagogies used in undergraduate education. One popular pedagogy is experiential learning (Abdulwahed and Nagy, 2009; DebBurman, 2002). Experiential learning addresses development of process skills such as critical thinking, oral and written communication, quantitative reasoning, and collaboration; all of which are skills students will need in the job market (DebBurman, 2002). Experiential learning is commonly referred to as learning by doing. These skills can be taught in the classroom and the laboratory setting. Implementation of experiential learning was associated with increased learning gains by students in science courses on pre/posttests, improvement in students' scientific process skills (i.e., communicating contemporary research and primary literature comprehension) and improved student attitudes towards science (Abdulwahed and Nagy, 2009; DebBurman, 2002). Experiential learning requires thoughtful and indepth course planning along with careful course scaffolding in order to be executed effectively (Tsui, 2013).

Problem-based Learning

Problem-based learning (PBL) uses learner-centered practices that focus on problem solving as a catalyst for self-directed learning gains, such as small groups and discussions where the faculty member is a facilitator of student inquiry (Tawfik *et al.*, 2014). Problem-based learning effectively enhanced learning gains in non-major biology students (Tawfik *et al.*, 2014). The use of real-world problems enhanced student interest in topics being taught and helped initiate discussions among students (Sahin, 2010). Problem-based learning was also associated with increased student interest and motivation in the classroom (Strobel and van Barneveld, 2009; Vernon and Blake, 1993) . Problem-based learning can be implemented in classrooms throughout many disciplines and is popular in the sciences, medical education, and economics at all levels of education (Strobel and van Barneveld, 2009).

Peer Instruction

Peer Instruction (PI) is a teaching approach that engages students in constructing their own knowledge and understanding of concepts by working with and learning from their peers (Porter *et al.*, 2011). A common way to implement PI is with the use of audience response systems (ARS) or clickers, where students are asked to answer a question then discuss their answer with their peers and evaluate if they will keep the original answer or change it, providing real time feedback of students' understanding to both faculty and students (Caldwell, 2007). Crossgrove and Curran (2008) studied the effects of clicker use in a non-major and a major biology course and found increased learning gains in both courses as well as increased retention of knowledge four months later when compared to the same courses where clickers were not used (Crossgrove and Curran, 2008). A review of 67 peer-reviewed papers from 2000-2007 revealed several benefits of clickers including improved classroom environment, improved learning, and improved student performance on formative and normative (compared to a curve not specific criterion) assessments (Kay and LeSage, 2009).

The above instructional methods are a sample of ways in which faculty can implement more learner-centered practices into their classroom. Each of them has their own benefits and drawbacks that instructors must take into consideration before their use. The difficulties of executing these practices and the lack of faculty training in teaching may be some of the reasons that the movement towards change in STEM teaching has not been as quick as was expected by professional organizations such as the NSF and AAAS (Dancy and Henderson, 2008).

Barriers to Change

> *"The challenges for educators in every discipline is for them to transition from being dispensers of facts to being architects of learning activities"* (Pierce and Fox, 2012).

Despite the increasing number of high-profile organizations calling for improvement of undergraduate STEM education, the amount of changes in STEM education are lacking (Borrego and Henderson, 2014). There are many published studies on why it is so hard for institutions and faculty to implement evidence-based teaching (Brownell and Tanner, 2012; Dancy and Henderson, 2008; Henderson, Beach, and Finkelstein, 2011). The three main barriers to change include insufficient training of faculty, lack of time, and lack of incentives (Henderson *et al.*, 2010). Faculty in STEM receive extensive training to become researchers yet very few obtain training to be teachers (Brownell and Tanner, 2012). There are a select number of professional development programs currently available that help postdoctoral scholars and new faculty train to become educators, such as the Faculty Institutes for Science Teaching IV (First IV, 2015) and the NAS/HHMI Summer Institutes for Undergraduate Biology Education (Pfund *et al.*, 2009). These programs tend to be exceptions and not the rule. In fact, the AAAS called for an increase in faculty training (AAAS, 2009) to help faculty better implement learner-centered teaching methods. Effective adoption and implementation of learner-centered strategies by faculty requires that faculty be trained in their use (Andrews *et al.*, 2011). Time is another reason that faculty give for not changing the way they teach students. Faculty must balance their research and teaching demands, taking into consideration that shaping a new pedagogical base for a course is labor and time intensive. Also, active learning teaching methods, when compared to more traditional lecture, are more time intensive. Personal identity as a scientist may also come into play as a barrier to change (Brownell and Tanner, 2012). How then do we address implementing evidence-based teaching while also addressing these barriers to change? One pedagogical model that is showing promise in bridging this gap is called the 'flipped classroom'.

The Flipped Classroom Model

> *"The key to the flipped class is actually not the videos, it is the freedom those videos give the teacher to have engaging class activities and interaction with their students" Jon Bergmann (2011).*

What is a Flipped Classroom?

We can bridge the gap between active-learning strategies and the traditional lecture strategy by implementing what is called blended learning. Blended learning combines the face-to-face interaction seen in a traditional classroom with an online instruction component (Bart, 2014). One such strategy is known as the flipped classroom. Defining the flipped classroom has been met with a lack of consensus; but one of the simplest definitions is inverting the classroom so that what traditionally took place inside the classroom now takes place at home and vice versa (Lage *et al.*, 2000). Lage *et al.*'s definition may not be the most accurate definition, however, because it does not encompass the types of activities occurring in the classroom (Bishop and Verleger, 2013). The in-class activities must focus on learner-centered instructional methods, ranging from peer instruction to experiential learning. Essentially, students watch lectures in the form of video podcasts (vodcasts) at home and participate in learner-centered activities within the classroom (Fig. 2). The blending of lecture and classroom activities allows faculty to introduce students to content material outside of class while engaging the students in applying what they learned in the classroom where the "expert" is available to address any misconceptions. The flipped classroom model is relatively new and there is still little research that examines its effectiveness in undergraduate biology courses and even less in non-major biology courses.

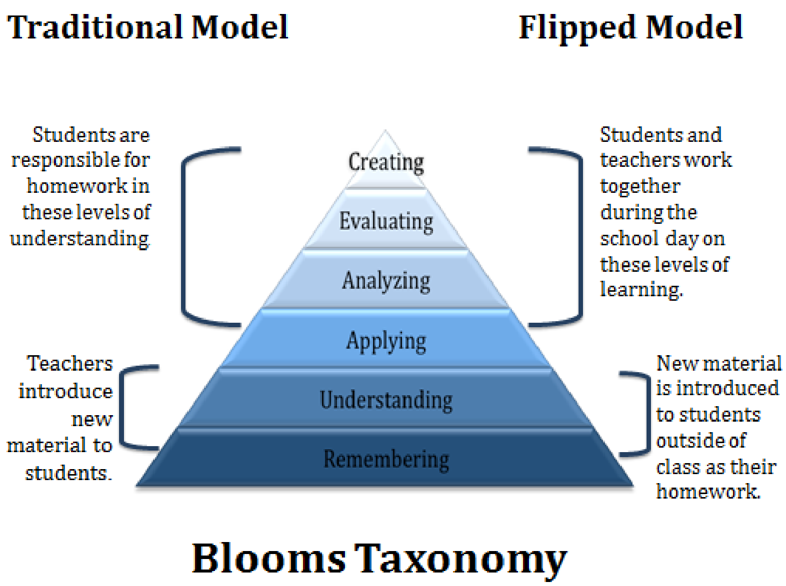

Fig. 2 Williams, Beth (2013). How I flipped my classroom.

Why Flipped Classroom may be the Answer

Many studies that look at barriers to change in undergraduate teaching refer to lack of time and training that faculty have in order to implement new teaching strategies (Brownell and Tanner, 2012; Henderson *et al.*, 2011). The flipped classroom allows faculty to dispense the same amount of material that would have been taught in traditional lecture but also allows them to receive real-time feedback about student understanding through the implementation of learner-centered activities. Traditional lecture is designed so that the instructor is the dispenser of knowledge and the student is a passive recipient of that information. The only feedback that the instructor receives from the student comes from exams, homework assignments and in-class questions. When the class is flipped, the instructor now receives real-time feedback in many forms such as answers to PI collaborations, class projects and group discussion. The flipped model may especially help faculty who are reluctant to eliminate traditional lecture all together. In fact, active-learning activities implemented by faculty in the classroom lead to learning gains in students not the flipped model itself (Knight and Wood, 2005). With the development of active- learning pedagogies and the ever advancing technology that faculty have at their disposal, the flipped classroom model is potentially easier to implement than ever before (McLaughlin *et al.*, 2014). The technological availability and diverse application methods could be reasons why there is so much “buzz” surrounding this pedagogy (Bishop and Verleger, 2013).

Flipped Classroom in STEM Higher Education

The application of flipped classrooms in STEM higher education has been studied in some disciplines such as pharmacology, statistics, engineering, biology, biochemistry, and public health, to name a few but more are needed. Pierce and Fox (2012) analyzed the implementation of a flipped classroom in a renal pharmacotherapy module by having students watch vodcasts of lectures prior to coming to class and then work on interactive case studies of patients with end stage renal disease. Student performance on the final exam improved significantly compared with students’ in traditional lecture; and student attitudes towards the flipped model were positive (Pierce and Fox, 2012). Galway *et al.* (2014) applied the flipped classroom model to an Environmental and Occupational Health course where students viewed material online then took a quiz before coming into class. That quiz was used to identify misconceptions, which were then addressed in the following class period using mini-lectures and various learning activities. Students self-reported increased knowledge as well as a positive learning experience, and had an increase in mean examination scores from 86.4 percent to 88.8 percent (Galway *et al.*, 2014). Metz (2015) investigated the impact of flipped classrooms in an introductory biology and a biochemistry course, where short videos (~20 min) were viewed outside of class and active-learning practices were held in class. These flipped sessions were sporadic throughout the semester but students still showed marginally improved test performances in the flipped cohort compared with the traditional course (Metz, 2015). In a non-majors biology course at a highly selective, doctoral granting university, students watched videos outside of class and worked on problem-based activities inside class. The non-flipped group studied the same material but the lectures were performed in class and the assignments outside of class. There was no significant difference in learning gains or attitudes between the two sets of students; however, active learning-strategies were used in both the flipped and non-flipped treatments (Jensen *et al.*, 2015). Furthermore, the effectiveness of a flipped classroom on increased learning gains in students has been shown to be due to active learning. When comparing a flipped classroom to one with active learning activities mixed in with lecture no differences were seen between the two treatments (Knight and Wood, 2005). Clearly, studies need to account for how they are characterizing a flipped classroom compared to how they are characterizing a traditional classroom.

Collectively, several studies to date indicated that the flipped classroom model is associated with improved student learning in STEM. Most published studies rely on the use of learning gains and motivation surveys only to measure differences between class types. The majority of studies did not take into consideration other variables, such as student and faculty academic backgrounds, which have been shown to influence the outcomes of educational studies (Theobald and Freeman, 2014).

Past Experimental Design Shortcomings

The most common ways in which researchers analyze the learning gains of students in treatment and control classrooms is by raw score changes, normalized gain scores, normalized change scores, and/or effect sizes; all of which fail to account for student and instructor equivalence (Theobald and Freeman, 2014). It is usually difficult to design randomized designs in educational studies because courses can only be offered at certain times and students have the ability to choose which courses and sections they take. One common shortcoming of educational experiments is that variables such as the instructor, the students, and the instructional methods are not taken into consideration; thus, the researcher cannot know if the outcomes of their study are from the intervention or differences between the treatment and control classes (Theobald and Freeman, 2014). Many studies are also conducted where a science education researcher is the instructor in the course being analyzed. These professors are likely to have more teaching expertise than the general population of instructors that are being called to change their teaching methods (Andrews *et al.*, 2011). Failure to consider the expertise of faculty can bias the results of studies and may not provide a true representation of gains that occur when implemented by faculty with less teaching expertise (Andrews *et al.*, 2011). My research is designed to address these deficiencies.

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CHAPTER 2

MANUSCRIPT

LIST OF FIGURES

LIST OF TABLES

IMPLEMENTATION OF A FLIPPED CLASSROOM IN A NON-MAJORS'S INTRODUCTORY BIOLOGY COURSE

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Changes to teaching practices in higher education have been requested in almost every field but their implementation can be daunting. The flipped classroom has become a popular method in both K-12 education and higher education for integrating more active learning in the classroom. Research on the implementation of flipped classrooms has been met with mixed results. We sought to determine the effectiveness of the flipped classroom while addressing methodology concerns cited by past studies including using both faculty and student demographic variables, addressing assessment performance using concept inventories and studying faculty who are not experts in education. Both flipped and non-flipped faculty self-reported approaching teaching in a similar way but when reviewed by external reviewers, flipped faculty implemented more active learning in the classroom. Flipping the classroom was associated with increased student's attitudes towards thinking scientifically but was also associated with decreased senior students' attitudes towards their aptitude for science. Decreased students' attitudes for needing science was associated with students who had higher GPAs. In terms of assessment performance, no meaningful difference was seen among groups (less than a question difference).

INTRODUCTION

The past two decades were full of demands for change in teaching practices in higher education (Spellings, 2006). The Science, Technology, Engineering, and Math (STEM) sector of education was no different. Calls for change came from organizations such as the Howard Hughes Medical Institute (HHMI), American Association for the Advancement of Science (AAAS), and the Office of the President, with an overwhelming majority calling for use of evidence-based teaching practices (AAAS and NSF, 2012; Bolliger and Wasilik, 2009; Olson and Riordan, 2012). There are indicators that biology majors are not receiving an education that provides them with an understanding of biological concepts (AAAS, 2009). Non-major students may be experiencing an even deeper lack of understanding since the majority of them are exposed to only 1-2 semesters of science education. If higher education institutions are to address the inefficiencies seen in the classroom, then we must implement teaching practices that we know to be effective for student learning (Freeman *et al.* 2014).

Instruction that actively engages students in the learning process increases learning gains by students in many disciplines including STEM (Armbruster *et al.*, 2009; Freeman *et al.*, 2014; Olson and Riordan, 2012). In a study of 15,000 college science professors, 200 professors reported using the flipped classroom model in their courses, citing reasons such as “students engaging in authentic scientific research” and “being able to use scientific equipment that is only available in the classroom” (Freeman and Schiller, 2013). The flipped classroom can be described as a method of instruction where passively obtained information is delivered outside of the classroom in the form of videos, podcasts, and readings and the information obtained through application is delivered inside the classroom in a form that is active and engaging to students (Bishop and Verleger, 2013). Although there are many ways in which one can implement active learning inside the college classroom, the flipped model may be especially attractive to faculty who want to use more effective teaching methods but are committed to dissemination of content information as part of the learning process and, therefore, are reluctant to eliminate traditional lecture all together (Faust and Paulson, 1998; Goodwin *et al.*, 1991).

With the development of varied active-learning pedagogies and ever-advancing teaching technology, the flipped classroom model is potentially easier to implement than ever before (McLaughlin *et al.*, 2014). The technological resources available, such as YouTube, Khan Academy, online simulations, and classroom clickers, offer a diverse range of ways in which the flipped classroom can be applied and allow for more feedback opportunities for both students and faculty. The only feedback that the instructor receives from the student in a traditional classroom comes from exams, homework assignments, and in-class questions. When the classroom is flipped, the instructor receives real-time feedback in many forms such as answers to peer instruction, collaborations, classroom projects, and group discussions, as well as through traditional quizzes and homework assignments about the content studied at home. Students also benefit from the real-time feedback from instructors and other students (Li *et al.*, 2010).

Despite the attractiveness of the flipped classroom approach to many instructors, there is little consensus on whether or not use of a flipped classroom is effective, with several studies citing the use of anecdotal evidence and personal experiences being the cause for so much “buzz” about the method (Andrews and Lemons, 2015; Bishop and Verleger, 2013; Freeman and Schiller, 2013; O'Flaherty and Phillips, 2015). Some research has shown merely ‘flipping your course’ will not help students learn unless the instructor effectively implements active learning (Baepler *et al.*, 2014; DeLozier and Rhodes, 2016; Jensen *et al.*, 2015). A growing amount of literature is providing evidence that faculty, STEM faculty in particular, are not necessarily trained to be instructors and may not be implementing active learning strategies effectively (Dancy and Henderson, 2008; Ebert-May *et al.*, 2015; Derting *et al.*, 2016; 2011; Henderson *et al.*, 2011). Varied effectiveness in faculty use of evidence-based practices (EBP) may be a major contributor to conflicting results in studies of flipped courses.

We examined how faculty implemented the flipped classroom in a non-major’s biology course and the impact ‘flipping’ had on students when compared with a traditional lecture approach. Previous studies relied on the use of learning gains and motivation surveys only for determining the effectiveness of a pedagogical implementation (Adams *et al.*, 2016; Baepler *et al.*, 2014; Day and Foley, 2006; Theobald and Freeman, 2014). These studies did not take into consideration student and faculty academic backgrounds, which can influence the outcomes of educational studies, especially in introductory courses (Theobald and Freeman, 2014). We designed our research to take student and faculty background into account to address the concerns cited by Theobald and Freeman. We hypothesized that 1) implementation of the flipped classroom model is associated with increased student-learning gains and more positive attitudes towards science and 2) faculty who flipped their classroom used more learner-centered teaching practices than those who used a lecture approach.

METHODS

IRB Approval

The study protocol was approved by the Murray State University Institutional Review Board (IRB, project #15-075). Students and faculty signed an IRB-approved consent form prior to participation in the study.

Study Participants

Students, 18 years or older, enrolled in Biological Concepts (BIO 101) during the Spring and Fall 2015 semesters participated voluntarily in our research during their first weekly laboratory meeting. We collected student data during laboratory rather than lecture sessions because more time was available for students to complete our assessments and surveys. We also invited all faculty who taught BIO 101 during the time frame of our study to participate, regardless of how they structured their classroom teaching. A total of seven faculty and 358 students participated during two semesters.

Course Description

Biological Concepts is a course offered at Murray State University (MSU) every semester as an elective that non-biology major students can select to fulfill the general education requirement in science. The course is designed to teach students the significance of biology in society and how it relates to agriculture, medicine, and the environment. Concepts taught in BIO 101 include evolution, cell structure and function, osmosis and diffusion, meiosis and mitosis, and photosynthesis and respiration. The class meets for three hours a week for 15 weeks and is accompanied by a 2-hour lab per week. Laboratories do not follow the same topic schedule as lecture and are taught by Graduate

Teaching Assistants. All students who participated in the study took the pre-assessments before any lecture/lab material was presented on the topics of osmosis and diffusion, as well as cellular respiration. The post-assessments were given after all lecture/lab material was taught on the assessed topics. Graduate Assistants must follow a predesigned lab schedule so all students received the same laboratory information during the same week. Although our research assessments were conducted during the laboratory sessions, our research focused on the learning that occurred during the class sessions that were taught by faculty.

Flipped and Non-Flipped Classroom Categorization

Faculty in the ‘flipped’ group agreed to provide students with video lecture content to study outside of class and to engage students in at least some learner-centered activities during class time. Learner-centered activities were anything that engaged the students inside the classroom, including small group discussions, "think-pair-share" questions, computer simulations, role-playing activities, and reflections. Video lectures were either recorded and supplied by MSU professors or obtained from external entities such as Khan Academy lectures (Khan Academy, 2015). Faculty in the ‘non-flipped’ group were asked to continue lecturing inside the classroom, without the use of learner-centered practices. Non-flipped faculty were permitted to assign homework outside of class in whatever format they chose.

Student Demographic and Attitude Surveys

Students first completed a Background Survey (Supplementary Materials). The survey was used to compile data on students' educational background, age, gender, part-time or full-time enrollment status, employment status while attending school, major, BIO 101 lecture instructor, and whether they were a traditional or non-traditional student. Students' GPA, SAT/ACT scores, and current number of math and science courses completed was obtained from the registrar's office upon participant permission.

Published validated instruments were used to assess the effectiveness of teaching approaches, as much as possible. We used instruments created by professionals of both education and science, leading to a higher quality of test question than assessments typically produced by faculty with less experience (Suskie, 2015). Use of published validated assessments helped to ensure the reliability of our results and allowed for comparison of our results with those of other researchers who used the same assessment. Students completed the Attitude Towards Science Survey (ATS; Udovic, 2014) to assess their general attitudes towards science classes at the beginning and end of the semester. Student’s also completed the Science Literacy Survey (SLS; Champagne, 1989), which asks participants to rank the importance of different aspects of scientific literacy such as the essentiality of being able to defend statements based on scientific evidence.

Concept Inventories

A concept inventory is a research-based test that assesses students understanding of one or more concepts. These tests are generally multiple-choice and are often administered at the beginning (pre-test) and end (post-test) of a course. Concept inventories typically give a clearer representation of a student’s subject understanding than course examinations because they are designed to include common misconceptions as distractors (Smith and Tanner, 2010). We selected two concept inventories based on their ability to distinguish understanding from misconceptions, relatively short length, and ease of grading objectively. Each assessment focused on a topic which was taught by all faculty participants, regardless of their area of research expertise or teaching background. These concept inventories were assigned pre/post treatment, with students taking them the first and last week of classes.

The Osmosis and Diffusion Concept Assessment (ODCA) is an 18 item, 2-tier, multiple-choice assessment that focuses on osmosis and diffusion. The first tier asks students a "what" question, where students analyze a situation and determine an outcome. The second tier asks for a justification of their answer in multiple-choice form. The ODCA was developed and modified over several years with the use of different subsets of students, reviewed by expert faculty, and interviews with students and faculty (Fisher and Williams, 2011). The inventory was tested with majors and non-majors during its validation, making it appropriate to use in our study. We scored the assessment using a key provided by the creators, assigning a point for each question answered correctly.

The Diagnostic Cluster Questions on photosynthesis and respiration (DQC) is an assessment composed of both multiple choice and short answer questions. The questions were taken from a larger concept inventory developed to study students' ability to trace the movement of matter through dynamic systems (Wilson *et al.*, 2006). The assessment is a 12-item inventory. We used the scoring rubric provided by the developers to score the pre- and post-assessments.

Faculty Surveys

Faculty who taught BIO 101 completed a Background Survey (Supplemental Materials) which provided data on faculty academic background including years of prior teaching experience, faculty type (adjunct, full professor, etc.), past participation in professional development in teaching, number of times they had taught BIO 101, and how many hours a semester they spent teaching osmosis/diffusion and photosynthesis/respiration. Faculty completed the Approaches to Teaching Inventory (ATI; Trigwell and Prosser, 2004) that indicates the degree to which an instructor supports the use of teacher-centered and learner-centered teaching approaches in a specific course. The ATI has been used in other studies in higher education to analyze faculty perceptions of their teaching strategies (Derting *et al.*, 2016; Ebert-May *et al.* 2015; Lasry *et al.*, 2014; Stes and Van Petegem, 2012; Trigwell and Prosser, 2004).

We also used the Teaching Practices Inventory (TPI; Gilbert and Wieman, 2014), which focuses on the teaching practices of STEM faculty. This 72-item inventory differs from the ATI in that it examines actual practices used in the classroom, reported by faculty, rather than faculty perceptions about their teaching.

Faculty participated in an exit interview (Supplemental Materials) after having taught their course for the semester. These interviews were recorded and transcribed in order to have a better understanding of how faculty interpreted the success of their semester. The interview questions were reviewed by a psychologist to make sure that the questions asked were truly appropriate for expected responses. The combination of the Background Survey, ATI, TPI, and interview constituted the self-report data that we collected from faculty participants.

External Analysis of Teaching Practices

Due to discrepancies between self-report data and data from external sources (e.g., Ebert-May *et al.*, 2011), we also assessed faculty teaching using external reviewers. Classroom observation protocols that utilize external reviewers provide an objective tool for assessing the extent to which a classroom is learner-centered (Budd and van der Hoeven Kraft, 2013). We video recorded each faculty participant for at least two of their class sessions during the semester in which they participated in the study. The Reformed Teaching Observation Protocol (RTOP) was used to score the videos because of its reliability and validity (MacIsaac and Falconer, 2002; Sawada *et al.*, 2002). The RTOP is a 25-item classroom observation tool that is standards-based, learner-centered, and inquiry-oriented (Sawada *et al.*, 2002). The RTOP assesses four pedagogical domains: lesson design and implementation, propositional and procedural knowledge, communicative interactions, and student-teacher relationships (MacIsaac *et al.*, 2001). Scores range from 0 to 100 with higher scores equating to more learner-centered classrooms. These scores are divided into five categories of learner-centered instruction with categories I and II representing teacher-centered, III indicating some learner-centered teaching, and IV and V being very learner-centered (Sawada *et al.*, 2002). Two trained RTOP reviewers scored each video and the average score for each faculty member was used for analysis. The reviewers were from institutions other than MSU and did not know the faculty in the videos.

Faculty and Student Demographics

A total of seven faculty participated in this study, four as flipped faculty and three as non-flipped (Table 1). Non-flipped and flipped faculty had the same years of teaching experience on average, but there was more variation in the years of teaching experience for non-flipped faculty. Flipped faculty had taught BIO 101 twice as often on average as non-flipped faculty.

Of the 358 students who participated in our research, the majority of them (81.37%) were of White descent, 8.39% where Black, 3.73% identified as Hispanic, and 4.03% were Asian students (Table 2). The remaining 2.48% identified as other. The majority of student participants were female (67.70%). Less than 1% of students did not identify themselves as male or female.

Statistical Analysis

Attributes (e.g., GPA, number of math and science courses, and year in school) of students in flipped and non-flipped classrooms were compared using Mann-Whitney-Wilcoxon Tests. Cumulative GPA was the only variable that differed significantly between class types and was, therefore, controlled for in analyses.

To analyze student survey data, we first reduced the large number of individual questions on the ATS and SLS to a small number of components using Principal Component Analysis (PCA). In the PCA, we used the pre-survey data from the student participants and data from 315 students who were enrolled in BIO 101 during the time period of our study, but whose professor was not a study participant. The resulting principal components were then used to compare data from students in flipped and non-flipped classes. Three principal components resulted from the ATS. The components were the same when the PCA was conducted with just pre-survey data from participant students and when conducted with data from nonparticipant students. We conducted a PCA with non-participant data in order to compare our results to a larger population. Principal component 1 encompassed nine ATS questions that related to thinking scientifically (TS), such as “Scientific ways of thinking are applicable in many areas of my life” (Supplemental Materials). Principal component 2 encompassed seven questions that related to the student’s aptitude for science (AS), such as “Even when a science class is interesting and the instructor tries to help me, we don’t learn very quickly, and often get discouraged” (Supplemental Materials). Principal component 3 encompassed four questions pertaining to one’s need to learn science (NS), such as “The things scientists do are not the concern of average people” (Supplemental Materials).

From the PCA two principal components were found on the SLS. Principal component 1 encompassed seven questions from the SLS that related to the importance of science in society (IS), such as “The importance to read and understand articles on science in the newspaper” (Supplemental Materials). Principal component 2 encompassed five questions from the SLS that related to the importance of assessing science (IS), such as “The importance to assess the appropriateness of the methodology of an experiment” (Supplemental Materials).

After determining principal components for both the ATS and SLS, we conducted a multinomial logistic regression (MLR) on each principal component to determine differences in student outcomes between class type (flipped and non-flipped) while controlling for GPA and year in school. Our outcome variable was the change in student attitude from the pre- to post-survey, which we categorized as increased attitude, no change, and decreased attitude.

Due to the small sample size, responses to faculty surveys were examined using means and standard error (S.E.). All analyses were conducted using R Statistical Software (2013). Data are presented as means ± S.E.

RESULTS

Teaching Practices

Faculty teaching flipped and non-flipped classes had similar perceptions of their use of conceptual change/learner-centered (CCLC) teaching approaches (3.19 ± 0.22 and 3.21 ± 0.24, respectively; where 5 = strongly agree). Faculty in each group neither agreed nor disagreed, overall, with CCLC teaching approaches. Faculty perceptions of information transfer/teacher-centered (ITTF) approaches with flipped faculty exhibiting stronger support for ITTF, scoring slightly higher (3.19 ± 0.24, where 5 = strongly agree) than non-flipped faculty (2.75 ± 0.30).

When asked about actual teaching practices using the TPI, faculty who taught flipped courses self-reported greater use of learner-centered teaching practices (31 ± 5.8 points) compared with faculty who taught non-flipped courses (25 ± 3.2 points. Interestingly, non-flipped faculty reported ‘stopping to ask questions’ more times per class session than did flipped faculty (Fig. 1). Flipped faculty reported frequently discussing why the material being learned was useful to their students, in contrast to non-flipped faculty who did not. Outside of the classroom, all flipped faculty assigned graded homework whereas only one non-flipped faculty member did.

The results from external reviewers supported the results from the TPI. On average, RTOP scores for flipped faculty were higher compared with faculty who taught non-flipped courses (Fig. 2). The average score of the non-flipped faculty was in category I that indicated straight lecture. Flipped faculty's average score placed them in the upper end of category II that indicated a lecture-based classroom, but with demonstration and minor student participation. Only one flipped faculty member scored in category III that was characterized by significant student engagement.

Student Learning and Attitudes

Class level and type were associated with a change in students' attitude toward science during a semester, based on the results of the ATS. The model for the first principal component, thinking scientifically, was not statically significant (Log-Likelihood: -318.81, McFadden R^2: 0.02, Likelihood ratio test: X^2= 12.3, p-value = 0.26), but significant effects of specific variables within the component did occur (Table 3a). Among students in the category 'increase in attitude', juniors had a significantly greater increase in their overall attitude toward science (i.e., more positive attitude) compared with first-year students. Also, the flipped approach to teaching was associated with a significantly greater increase in attitude toward thinking scientifically compared with the non-flipped approach. None of the variables were associated significantly with the 'decrease in attitude' category for the thinking scientifically component of the ATS.

The overall model for the second component, aptitude for sciences, was also not statistically significant (Log-Likelihood: -337.06, McFadden R^2: 0.03, Likelihood ratio test: X^2= 17.70, p-value = 0.06), but significant effects of a specific variable did occur (Table 3b). Among students in the category 'decrease in attitude', seniors had a significantly greater decrease in their overall attitude toward science (i.e., more negative attitude) compared with first-year students. None of the variables were associated significantly with the 'increase in attitude' category for the aptitude component in attitude towards science for students.

The overall model for the third component, ability to learn science, was statistically significant (Log-Likelihood: -166.43, McFadden R^2: 0.07, Likelihood ratio test: X^2 = 24.29, p-value = 0.01) and significant effects of specific variables also occurred (Table 3c). Among students in the category 'decrease in attitude', sophomores had a significantly greater decrease in their overall attitude toward science (i.e., more negative attitude) compared with first-year students. Also, there was a negative relationship between cumulative GPA and attitude towards learning science. None of the variables were associated significantly with the 'increase in attitude' category for the learning science component in attitude towards science.

When analyzing the SLS, the overall model was not significant for the assessing science component (Log-Likelihood: -335.71, McFadden R^2: 0.02, Likelihood ratio test: X^2 = 14.67, p-value = 0.14) or the importance of science in society component (Log-Likelihood: -338.72, McFadden R^2: 0.02, Likelihood ratio test: X^2 = 12.74, p-value = 0.24). None of the predictors within the model for either component was significant (Table 4a and 4b).

Student Learning Outcomes

Osmosis and Diffusion Concept Assessment

Pre-score, ethnicity, GPA, and class type were associated significantly with learning outcomes from the ODCA. The best regression model (Table 5; R^2=0.33, $F_{(9,311)}$ =17.25, p<0.001) for the ODCA assessment post-score included gender, ethnicity, class type, GPA, number of math courses completed, and the student's pre-score. The model explained 33% of the variance in post-test scores.

Students of White ethnicity made up the majority of our sample size (81%) so the scores of White students were used as the baseline for comparisons in the regression analysis (Table 6). Post-test scores for Black students differed significantly from those of White students, with Black students scoring 8.7% lower on average on the post-test compared with White students (Table 6). There was no statistically significant difference among Asians, Native Americans, Hispanics, or students of other descent compared with White students.

Cumulative GPA was positively associated with student scores on the ODCA while the number of math courses taken and being in a flipped classroom had a small negative association with the post-score. A one-unit increase in GPA was associated with a 5% increase in a student's post-test score (Table 5). Students' post-score decreased by 1.8% with each additional math course that a student had taken (Table 5). Lastly, the predicted post-test score was 3.5% lower if a student was in a flipped rather than non-flipped class (Table 5). The effect of number of previous math courses taken (1.8%) equates to the difference of 1.8 points on a 100-point exam. GPA (5.1%) and the class type (3.5%) equate to 5 and 3.5 points on a 100-point exam respectively.

Diagnostic Question Clusters

Pre-Score, ethnicity, and GPA were associated significantly with learning outcomes on the DQC. The best regression model for the DQC assessment post score (Table 6,

R^2=0.14, $F_{(7,313)}$ =7.005, $p<0.001$) included ethnicity, GPA, and the student's pre-score. Pre-score was a significant predictor of post-score on the DQC and explained 22.7% of the variance in the post-test scores. As a student's pre-test score increased by a unit (1% point) their post-test score increased by 23% (Table 7). Ethnicity was also a significant predictor of the post-score (Table 7). Black students, on average, scored 2.5% lower on the post-test compared with White students. There was no statistical difference between Asians, Native Americans, Hispanics or students of other descent compared with White students. Cumulative GPA had a very slight but significant association with the post-test score. As a student's GPA increased by one unit, their post-test score increased by 1%. There was no significant association between class type, gender, or the number of previously taken science courses on the DQC.

DISCUSSION

Previous research indicated that it is not the flipping of a classroom that leads to increased learning gains by students but rather the effective implementation of learner centered activities (Baepler *et al.*, 2014; Jensen *et al.*, 2015). In our study, the lack of major differences in student learning gains and attitudes was consistent with the occurrence of only minor differences in teaching methods between flipped and non-flipped faculty.

Faculty

From the RTOP analyses conducted on the participating faculty we saw only slight differences in categorization of the nature of the classroom between the majority of flipped and non-flipped classrooms. Three of the four flipped faculty taught with the majority of class time being lecture with engaging activities being used only to a minor extent (Category II), with only one flipped faculty member conducting a classroom with significant engagement (Category III). Flipped faculty reported support for more ITTF approaches to teaching (ATI) indicating that they still approach their teaching strategies from an information transfer perspective. Faculty support for ITTF was consistent with their use of lecture as their primary teaching practice.

Based on interviews with flipped faculty, several barriers to implementing inquiry-based teaching methods were apparent such as a "lack of confidence" in implementing learner-centered teaching practices and a sense of pressure of "not having enough time" to teach topics or implement a new teaching method. Many participants cited wanting students to leave BIO 101 with a basic understanding of biological concepts, however, their confidence in the students' abilities to do this was low. Faculty's lack of confidence in their own ability to implement a flipped classroom may account for their reliance on lecture-based teaching practices and only minor interaction with students.

The difficulty faculty had implementing active learning activities into their classroom, as required by the flipped classroom model, was not new; many studies have shown that change is hard when it comes to implementing evidence-based teaching practices that differ from straight lecture (Brownell and Tanner, 2012; Dancy and Henderson, 2010; Derting *et al.*, 2016; Ebert-May *et al.*, 2011; 2015; Michael, 2007). The lack of ongoing professional development, most faculty participate in, without follow-ups and monitoring leads to a continuation of ineffective teaching (Ebert-May *et al.*, 2011; 2015; Sunal *et al.*, 2001). Only one participant of our flipped faculty had participated in an extended program of professional development as well as ongoing programs and that professor was the only professor to implement a truly active learning class (Category III).

Students

We predicted that student learning gains would be greater in flipped compared with non-flipped classrooms, as has been shown using quizzes and tests. Our results supported those of past studies, showing that it is not the flipping that influences student learning gains but rather the active learning taking place in the classroom (Baepler *et al.*, 2014; DeLozier and Rhodes, 2016; Jensen *et al.*, 2015). Our results indicated that students in non-flipped classrooms performed better on one (the ODCA) of two assessments of content knowledge. The negative association between flipped classrooms (-3.5%) and the students' performance on the ODCA equated to less than a one-question difference in performance (each question was worth 1 point, the difference seen was 0.63 points). Further research is suggested for building a stronger model for predicting the post-score on the ODCA, as the R^2 (0.33) was low.

No difference was seen on the DQC between groups. Therefore, from a practical standpoint, no performance differences occurred between groups. These results were consistent with prior reports of a lack of student learning improvements when untrained faculty implement active learning in their classes (Andrews *et al.*, 2011). However, a meta-analysis of over 200 active-learning classrooms showed that active learning, as used in flipped classrooms, was associated with increased learning gains (Freeman *et al.*, 2014). For both the DQC and ODCA, students with a high pre-score had higher post-scores. Thus, the students with the best knowledge of course material at the beginning of a semester were able to learn regardless of the teaching used. These results also suggest that a better understanding of a concept at the beginning of the course allowed for more clarification of misconceptions (Crouch and Mazur, 2001). In contrast with the ODCA, the DQC is a short answer concept inventory where students do not just answer multiple-choice questions but must explain why their chosen answer is correct. It is interesting that GPA was associated with a 5% increase on the ODCA but only a 1% increase in the DQC. This could be explained by the difference in assessment design. The requirement for an explanation on the DQC could reveal that students did not have as deep of an understanding as one would assume by choosing the correct answer alone. Class size could also play a role. Freeman *et al.* (2014) found that the optimal class size for active learning was 50 students or fewer. Our BIO 101 course has an enrollment cap of 80 students and most sections are full.

Although little difference was seen in how teaching practices were used in the classroom, differences in students' attitudes occurred between class types, suggesting that implementing even minimal amounts of engaging activities can lead to an increase in thinking scientifically. Increasing scientific thinking was seen as part of the initiative set out by Vision and Change (AAAS, 2009). Seniors were more likely to decrease their attitude towards their aptitude for science at the end of the semester. The more negative attitude may be due to a fear of science which may be why they waited so long to take BIO 101 or this could have been the first time the student was exposed to this type of instruction which lead to negative views (Crouch and Mazur, 2001; Freeman and Schiller, 2013). However, it is important to note that the small sample size of seniors (flipped = 23, non-flipped = 8) in this study, spread among the dependent variables may be the reason for the significance found. Student's with higher GPAs also had decreased attitudes towards needing science, which is alarming in a non-major's biology course and goes against the literature. The increase in attitudes towards thinking scientifically by students in flipped classrooms may be due to their chance to interact with the material in the classroom more so than listening to a lecture over it. However, the research on how flipped classroom influences students attitudes has been filled with mixed results (Bishop and Verleger, 2013; Floro, 2014; Rae and O'Malley, 2017).

Our study addresses the call for studies about active learning that encompass student changes in attitudes and learning gains while accounting for variables such as GPA, previous courses taken, and demographic variables (Freeman *et al.*, 2014). Our study also addresses biases that may be exhibited by studies whose investigators are also the instructors in the study. Our study was conducted in an attempt to understand how implementing a flipped classroom affects faculty and students in the typical college classroom taught by STEM faculty who do not have as much faculty development training as education experts. However, the design of our study comes with limitations such as the limited number of faculty participants. The flexibility that we provided to faculty may have allowed variation in material and EBP among flipped classrooms potentially leading to an increase in variability between classrooms designated as flipped. Also, students were not randomly assigned to a classroom but were allowed to choose the classes in which they were enrolled in. Future research on flipped classrooms should include a stricter ‘flipped’ curriculum that lowers the variability of instruction seen within class types and should include more participating faculty so demographics can be analyzed.

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Table 1. Demographic and background characteristics of Flipped and Non-flipped Faculty

Demographic/background variable	Non-flipped (n=3)	Flipped (n=4)
Average Years Teaching Experience	11.2 ± 8.6	11.3 ± 3.2
Prior Faculty Development Participation	67%	50%
Gender Ratio (M:F)	3:0	1:1
Average Times Taught Biology 101	7.2 ± 4.5	13.7 ± 12.2

Table 2. Demographic and background characteristics of Flipped and Non-flipped Students

Demographic/background variable	Non-flipped (n=128)	Flipped (n=230)
Number of Previous Math Courses	1.7 ± 0.10	1.7 ± 0.09
Mean GPA	3.1 ± 0.06	2.8 ± 0.19
Gender Ratio (M:F)	1:2	4:9
Mean Year in School	1.8 ±0.07	1.7 ± 0.06

Table 3a. Multinomial logistic regression analysis of the thinking scientifically component from the Attitudes Towards Science Survey (n=334) for students whose attitudes increased (n= 59) or decreased (n= 84) compared with stayed the same (n=191). First-year students and Non-flipped class type were the base group for comparisons.

	Increase in Attitude			Decrease in Attitude		
	Relative Risk Ratio (95% CI)	SE	P Value	Relative Risk Ratio (95% CI)	SE	P Value
INTERCEPT	0.2 (0-0.8)	0.8	0.0*	0.6 (0.2-2)	0.6	0.4
CLASS TYPE: FLIPPED	0.5 (0.3-0.9)	0.3	0.0*	0.9 (0.5-1.6)	0.3	0.8
CUMULATIVE GPA	1.3 (0.8-2.1)	0.2	0.3	0.9 (0.6-1.4)	0.2	0.8
SOPHMORE	1.7 (0.8-3.5)	0.4	0.1	0.8 (0.4-1.5)	0.3	0.4
JUNIOR	2.5 (1-6)	0.4	0.0*	1.3 (0.6-2.9)	0.4	0.5
SENIOR	1 (0.3-3.1)	0.6	1.0	0.8 (0.3-2)	0.5	0.6

Table 3b. Multinomial logistic regression analysis of the aptitude science component from the Attitudes Towards Science Survey (n=334) for students whose attitudes increased (n= 67) or decreased (n= 163) compared with stayed the same (n=104). First-year students and Non-flipped class type were the base group for comparisons.

	Increase in Attitude			Decrease in Attitude		
	Relative Risk Ratio (95% CI)	SE	P Value	Relative Risk Ratio (95% CI)	SE	P Value
INTERCEPT	0.1 (0.6-2.5)	0.8	0.5	0.2 (0.7-2.3)	0.6	0.6
CLASS TYPE: FLIPPED	0.6 (1.3-2.5)	0.3	0.5	0.5 (0.8-1.4)	0.3	0.5
CUMULATIVE GPA	0.6 (0.9-1.5)	0.2	0.8	1 (1.4-2.1)	0.2	0.1
SOPHMORE	0.5 (1.1-2.3)	0.4	0.8	0.4 (0.7-1.3)	0.3	0.3
JUNIOR	0.8 (2.1-5.3)	0.5	0.1	0.4 (1-2.3)	0.4	1.0
SENIOR	0.4 (1.1-2.9)	0.5	0.9	0.2 (0.4-1)	0.5	0.0*

Table 3c. Multinomial logistic regression analysis of the learn science component from the Attitudes Towards Science Survey (n=334) for students whose attitudes increased (n= 16) or decreased (n= 281) compared with stayed the same (n=37). First-year students and Non-flipped class type were the base group for comparisons.

	Increase in Attitude			Decrease in Attitude		
	Relative Risk Ratio (95% CI)	SE	P Value	Relative Risk Ratio (95% CI)	SE	P Value
INTERCEPT	0 (0.1-1.5)	1.6	0.1	0.5 (2.5-12.2)	0.8	0.2
CLASS TYPE: FLIPPED	0.4 (1.4-4.8)	0.6	0.6	0.5 (1.1-2.3)	0.4	0.8
CUMULATIVE GPA	0.6 (1.6-4.1)	0.5	0.3	1 (1.7-2.9)	0.3	0.0*
SOPHMORE	0.4 (1.5-6.5)	0.7	0.6	0.1 (0.3-0.6)	0.4	0.0*
JUNIOR	0.3 (1.6-9.8)	0.9	0.6	0.2 (0.5-1.3)	0.5	0.2
SENIOR	0.1 (1.5-20.9)	1.4	0.8	0.2 (1-4.8)	0.8	1.0

Table 4a. Multinomial logistic regression analysis of the assessing science component from the Science Literacy Survey (n=334) for students whose attitudes increased (n= 74) or decreased (n= 88) compared with stayed the same (n=172). First-year students and Non-flipped class type were the base group for comparisons.

	Increase in Attitude			Decrease in Attitude		
	Relative Risk Ratio (95% CI)	SE	P Value	Relative Risk Ratio (95% CI)	SE	P Value
INTERCEPT	0.3 (1-3.9)	0.7	1.0	0.3 (1.1-3.8)	0.6	0.9
CLASS TYPE: FLIPPED	0.4 (0.7-1.3)	0.3	0.3	0.6 (1.1-1.9)	0.3	0.8
CUMULATIVE GPA	0.5 (0.8-1.2)	0.2	0.2	0.6 (0.8-1.2)	0.2	0.3
SOPHMORE	0.5 (1-2)	0.4	1.0	0.4 (0.8-1.6)	0.3	0.6
JUNIOR	0.8 (1.8-4)	0.4	0.1	0.1 (0.4-1)	0.5	0.1
SENIOR	0.4 (1.1-2.9)	0.5	0.8	0.2 (0.6-1.5)	0.5	0.3

Table 4b. Multinomial logistic regression analysis of the importance of science in society component from the Science Literacy Survey (n=334) for students whose attitudes increased (n= 80) or decreased (n= 84) compared with stayed the same (n=170). First-year students and Non-flipped class type were the base group for comparisons.

	Increase in Attitude			Decrease in Attitude		
	Relative Risk Ratio (95% CI)	**SE**	**P Value**	**Relative Risk Ratio (95% CI)**	**SE**	**P Value**
INTERCEPT	0.2 (0.7-2.6)	0.6	0.6	0.1 (0.3-1.3)	0.7	0.1
CLASS TYPE: FLIPPED	0.5 (0.8-1.5)	0.3	0.5	0.8 (1.4-2.5)	0.3	0.3
CUMULATIVE GPA	0.6 (0.9-1.4)	0.2	0.7	0.7 (1-1.5)	0.2	1.0
SOPHMORE	0.2 (0.5-1)	0.4	0.1	0.7 (1.3-2.5)	0.3	0.4
JUNIOR	0.5 (1.1-2.4)	0.4	0.8	0.3 (0.8-2.1)	0.5	0.7
SENIOR	0.4 (1.1-3.1)	0.5	0.8	0.8 (2.1-5.1)	0.5	0.1

Table 5. Multiple regression analysis of ODCA Results.

	Estimate	**Std. Error**	**t value**	***p***	
INTERCEPT	0.229926	0.0397	5.792	1.71E-08	***
PRE-SCORE ODCA	0.418734	0.049926	8.387	1.76E-15	***
ETHNICITY: BLACK	-0.087464	0.027163	-3.22	0.00142	**
ETHNICITY: ASIAN	-0.026151	0.039265	-0.666	0.50589	
ETHNICITY: HISPANIC	0.04935	0.038859	1.27	0.20505	
ETHNICITY: NATIVE AMERICAN	-0.046708	0.093174	-0.501	0.61652	
ETHNICITY: OTHER	0.068286	0.055307	1.235	0.21789	
CUMULATIVE GPA	0.050683	0.011591	4.372	1.68E-05	***
CLASS TYPE: FLIPPED	-0.035015	0.015607	-2.244	0.02556	*
# PREVIOUS MATH COURSE	-0.018119	0.005815	-3.116	0.002	**

Table 6. Multiple Regression Analysis Of DQC Results.

	Estimate	**Std. Error**	**t value**	***p***	
INTERCEPT	0.50	0.03	14.72	< 2e-16	***
PRE-SCORE DQC	0.23	0.05	4.59	6.52E-06	***
ETHNICITY: BLACK	-0.03	0.01	-2.93	0.02	**
ETHNICITY: ASIAN	0.01	0.01	0.49	0.62	
ETHNICITY: HISPANIC	0.00	0.01	-0.16	0.87	
ETHNICITY: NATIVE AMERICAN	0.01	0.03	0.28	0.78	
ETHNICITY: OTHER	0.00	0.02	-0.11	0.91	
CUMULATIVE GPA	0.01	0.00	2.53	0.01	*

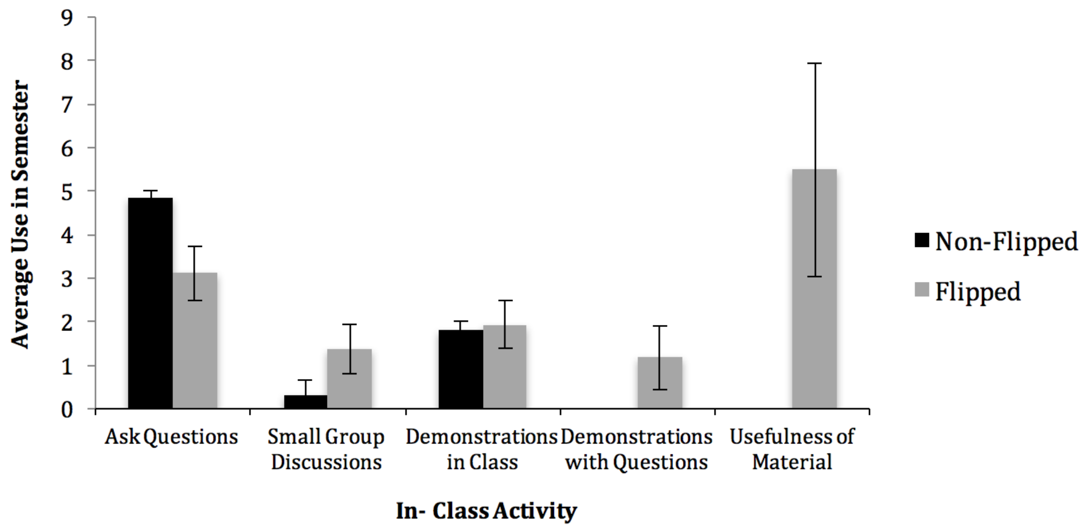

Figure 1. Comparison of inside the classroom activities reported by faculty in flipped and non-flipped classrooms (mean ± SE).

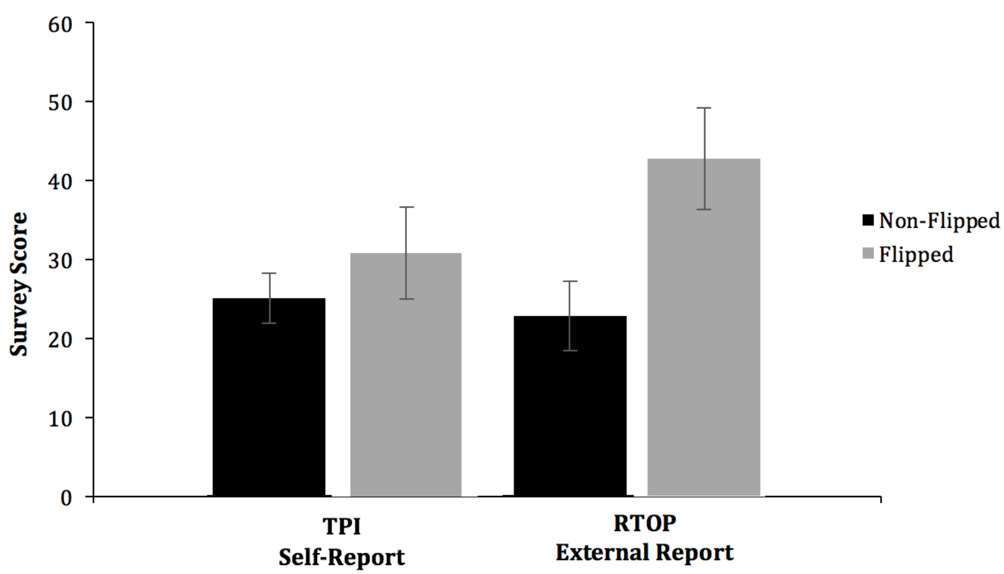

Figure 2. Comparison of self-report (TPI) and externally reviewed (RTOP) teaching practices reported in flipped and non-flipped classrooms.

SUPPLEMENTAL MATERIALS

Table 3. Summary of Principal Component Analysis of student responses, at the beginning of a semester, to the Attitudes About Science Survey (n= 651).

Item	**Nature of Science**	**Science as a Subject**	**Need for Science**
It might take some effort for me to understand many unfamiliar scientific concepts, but I would be able to succeed in most cases.	**0.56**	0.01	0.21
Science classes require creative thinking, just as a design class or creative writing class does.	**0.49**	0.01	0.04
The things that scientists do are not the concern of average people.	-0.11	0.12	**0.52**
Science deals mostly with facts and figures; when language is used, it tends to be complex jargon. Therefore, good writing ability is not necessary in a science class.	-0.25	0.18	0.24
Even when a science class is interesting and the teacher tries to help me, I don't learn very quickly, and often get discouraged.	0.16	**0.83**	-0.07
The kinds of skills needed by students in a science class are not that different from those needed in other classes.	0.15	-0.3	0.3
Our country would be better off if more people had a basic understanding of science.	**0.7**	0.07	0.03
Although logical and analytical thinking are necessary to do well in a science class, this kind of thinking is applicable in many fields besides science.	**0.65**	-0.01	0.11
Science is too complex a subject for me to learn much about it.	-0.02	**0.79**	0.15
Science classes require very different skills than those required by other kinds of classes.	-0.03	**0.47**	-0.11
Scientific work would be too hard for me.	0.05	**0.78**	0.14
There are things that one can learn by studying science that are useful no matter what kind of job one has.	**0.62**	-0.04	-0.05
People that do well in science classes tend to have a certain kind of mindset, typically an analytical, linear, math-oriented personality, that allows them to succeed in science but hinders them in other fields.	0.15	**0.4**	0.2
In general, I feel good about my ability to learn about science.	0.11	**-0.75**	0.06
I don't think I'll ever be in a position in which I'll be able to use scientific knowledge.	-0.25	0.24	**0.53**

Item	Nature of Science	Science as a Subject	Need for Science
It would be a waste of time for me to try to study science.	**-0.42**	0.22	**0.44**
If I have children, they will learn about science in school, so I won't need to help them learn about it.	**-0.48**	-0.06	0.35
Scientific ways of thinking are applicable in many areas of life.	**0.69**	-0.12	-0.06
I feel confident about my ability to do basic scientific work.	0.12	**-0.71**	0.18
If I were interested in areas of science other than ones learned in class, I would be able to learn more on my own.	0.35	-0.22	**0.56**
People need to understand the nature of science because it has such a great effect upon their lives.	**0.71**	-0.01	-0.02
People that are good at science can be good in other areas, as well.	**0.63**	0.11	-0.12
I would rather spend my school time learning something more useful than science.	-0.23	0.34	0.36
The people that I have known that were good at science were never good at anything else.	-0.3	0.05	0.42
Eigenvalues	4.40	4.01	2.02
% of variance	18	17	8
α	.8	.83	.6

Table 4. Summary of Principal Component Analysis of student responses, at the beginning of a semester, to the Attitudes Towards Science Survey (n= 618).

Item	Science Importance to Society	Assess Science
Pose a question that can be addressed by the scientific method, e.g. state a hypothesis.	-0.09	**0.78**
Provide a scientific explanation for a natural process, e.g. photosynthesis, digestion, combustion.	-0.03	**0.75**

Item	Science Importance to Society	Assess Science
Assess the appropriateness of the methodology of an experiment.	0.14	**0.64**
Read and understand articles on science in the newspaper.	**0.62**	0.08
Read and interpret graphs displaying scientific information.	0.36	0.37
Believe that scientific knowledge is worth pursuing even if it never yields practical benefits.	0.23	0.45
Define basic scientific terms, e.g. DNA, molecule, electricity.	0.24	**0.50**
Design an experiment that is a valid test of a hypothesis.	0.03	**0.75**
Engage in a scientifically informed discussion of a contemporary issue, e.g. should a child with AIDS be allowed to attend public school.	**0.83**	-0.26
Assess the accuracy of scientific statements, e.g. the seasons change with the distance of the earth from the sun.	**0.69**	0.13
Give an instance of how a scientific discovery or idea has affected society, e.g. the germ theory of disease.	**0.62**	0.19
Be inclined to challenge authority on evidence that supports scientific statements.	**0.65**	0.00
Describe natural phenomena, e.g. the phases of the moon.	**0.56**	0.27
Apply scientific information in personal decision-making, e.g. ozone depletion and the use of aerosols.	**0.70**	0.09
Locate valid scientific information when needed.	0.37	0.42
Eigenvalues	3.91	3.49
% of variance	26	23
α	0.83	.82

Interview Questions:

Interview Sequence of Questions

Do I have your permission to record the interview?

What do you want your students to know and be able to do after completing BIO 101?

> What is your role as the professor in making that happen?
>
> What is the role of the students in making that happen?

Before participating in this study, had you ever considered changing how you taught in the classroom? Why or why not?

> If yes, what have you wanted to try?
>
> What stopped you from implementing (If they didn't)?

What does 'flipped classroom' mean to you?

> How does it compare to an 'unflipped' classroom?

Tell me about teaching Bio 101 this semester. Was your experience different than what you expected? If so, How?

> If no, have you ever thought of supplementing your instruction with online instructional videos?
>
> If yes, did adding the online components (instructional video) change what happened in your classroom? If so, how?
>
> Did you incorporate the information from the instructional videos into the next day's class session at all? If so, How?
>
> What sort of activities did you use during class time?
>
> How did you motivate your students to complete assignments outside of class?
>
> How did you motivate your students to complete assignments inside of class?

Do you think you would ever 'flip' your BIO 101 class (control)?

Do you think you would ever 'flip' your BIO 101 class again (experimental)?

If yes, why do you think you would?

If no, would you flip a different course? Why?

IRB APPROVAL

MURRAY
STATE UNIVERSITY

PROVOST AND VICE PRESIDENT
FOR ACADEMIC AFFAIRS
Institutional Review Board
328 Wells Hall
Murray, KY 42071-3318
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TO: Terry Derting
Department of Biological Sciences

FROM: Institutional Review Board
Sally Mateja, CIP, IRB Coordinator

DATE: December 4, 2015

RE: Human Subjects Protocol I.D. - IRB 15-o75

On behalf of the IRB, I have reviewed your request for an amendment to your student's Level 1 protocol entitled "Assessment of the Implementation of Flipped Classroom in Non-Major Biology Course." After review and consideration, I have determined that the change to the research will be conducted in compliance with Murray State University guidelines for the protection of human participants. You may begin data collection with the updated survey form now.

The approved cover letter has already been returned to you along with the materials that were previously reviewed for use in this study. The new approved survey form is attached to this letter. These are the forms and materials that should have been presented to the subjects. Use of any process or forms other than those approved by the IRB will be considered misconduct in research as stated in the MSU IRB Procedures and Guidelines section 20.3.

This Level 1 approval is valid until November 16, 2016. If data collection and analysis extends beyond this time period, the research project must be reviewed as a continuation project by the IRB prior to the end of the approval period, November 16, 2016. You must reapply for IRB approval by submitting a Project Update and Closure form (available on the Institutional Review Board web site). You must allow ample time for IRB processing and decision prior to your expiration date, or your research must stop until such time that IRB approval is received. If the research project is completed by the end of the approval period, then a Project Update and Closure form must be submitted for IRB review so that your protocol may be closed. It is your responsibility to submit the appropriate paperwork in a timely manner. As a courtesy, a reminder letter may be sent to you.

The amendment to the protocol is approved.

App. 2/3/12