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IMPACT OF AN ACTIVE LEARNING INTERVENTION ON STUDENT SUCCESS IN AN INTRODUCTORY-LEVEL BIOLOGY COURSE

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IMPACT OF AN ACTIVE LEARNING INTERVENTION ON STUDENT SUCCESS IN AN INTRODUCTORY-LEVEL BIOLOGY COURSE

by

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ABSTRACT

Large enrollment introductory-level courses with high rates of students receiving a D, F, or withdrawing have been identified within higher education as gateway courses. Students not successfully completing these courses are disproportionately represented by historically and continually marginalized populations, such as low-income, poorly represented ethnic groups, and first-generation students. A form of blended learning called the flipped class model is becoming increasingly prevalent in gateway courses. A flipped class design may reduce the cognitive load by allowing time for processing information before class while cooperative learning may result in a collective working memory effect where social interactions may serve to fill in gaps in knowledge and preparedness. However, this can be difficult to implement in large-enrollment courses.

This study focused on the efficacy of a flipped class intervention, combined with the implementation of a Learning Assistant model, at increasing student success in a high enrollment, introductory-level biology course. Student success was measured by comparing mean exam scores and DFW rates (percentage of students earning a D, F, or, withdrawing) for course sections taught in a traditional didactic style to those of course sections employing a flipped class design. Student perceptions of personal learning gains were explored through the implementation of a Student Assessment of Learning Gains survey utilizing Likert-type and open-ended questions. Data revealed a significant increase in exam score means for course sections taught with a flipped class design compared to those taught traditionally. No significant difference was observed for overall DFW rates between course designs, nor did course design produce a significant difference in DFW rate when controlling for Pell grant eligibility or first-generation status. However, the analysis uncovered a significant interaction between course design and ethnic groups for reported DFW rates. Evaluation of survey responses showed a significant increase in mean response scores for questions related to the perceived benefits of active learning and cooperative learning on understanding and overall learning gains for flipped class sections compared to traditional sections. A thematic analysis of open-ended survey responses yielded an overall pervasive theme of group work with tightly related sub-themes of cooperative learning and activities.

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DEDICATION

This body of work is dedicated to my family. My true North. To my mother, the gentle sun which warms my heart and dries my tears. To my father, the steady wind at my back calmly steering me toward the right path. To my sister, a welcome voice of reason and encouragement. To my daughter who quite literally saved my life. To my son who reminded me how to smile. To my friends, my chosen family, a never-failing system of support, and a cheering section like no other. Thank you all for your unconditional love and support and for believing in me even when I did not believe in myself.

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LIST OF ABBREVIATIONS

AAU	Association of American Universities
ACE	American Council on Education
ACUE	Association of College and University Educators
AL	Active Learning
BEES	Biological, Environmental and Earth Sciences
BSC 110	Principles of Biological Sciences I
CL	Cooperative Learning
CLT	Cognitive Load Theory
DFW	Course grade of D, F, or course withdrawal
G2C	Gateways to Completion
LA	Learning Assistant
STEM	Science, Technology, Engineering & Math
QEP	Quality Enhancement Program
USM	The University of Southern Mississippi

CHAPTER I - INTRODUCTION

Background

Large enrollment introductory-level courses with high DFW rates (course grade of D, F or course withdrawal) have been identified within higher education as gateway courses (Koch & Rodier, 2014). The largest percentage of students not successfully completing gateway courses, and subsequently less likely to persist to degree completion, are disproportionately represented by historically and continually marginalized populations, such as low-income, poorly represented ethnic groups, and first-generation students (Koch, 2017). Koch (2017) reports DFW rates in gateway courses between 32 – 42% for people of color compared to 22% for white students revealing disturbing trends in academic inequities. Surveying over 30 institutions of higher education, Koch and Rodier (2014) reported the average DFWI rate for a General Biology course was close to 30%, but that rate was approximately 16% higher for African American students.

Gateways to Completion (G2C)

In 2016, The University of Southern Mississippi (USM) Quality Enhancement Plan, Eagles Engaged, was launched in partnership with the John N. Gardner Institute Gateways to Completion (G2C) program. The G2C program is a three-year, evidence-based effort to analyze, reform, and monitor progress for gateway courses with the goal of lowering DFWI rates, especially for historically marginalized populations, such as low-income and first-generation students. Unique features of the G2C program include a focus on large-enrollment courses to maximize impact, integration with existing institutional processes, and faculty support networks (John N. Gardner Institute, 2018).

The first stage of the G2C program at USM involved identifying five gateway courses at USM to be included in the initiative. The five courses identified were: Biological Sciences I, Human Anatomy and Physiology I, General Chemistry I, Intermediate Algebra, and World Civilization I. For each of the five courses, Key Performance Indicators were summarized and based on the findings, and interventions were proposed to improve student learning outcomes. This was followed by the implementation of one or more of the proposed interventions, such as course redesigns, course prerequisites, supplementary co-requisites, and peer-to-peer instructional models for each gateway course. Completion of the G2C initiative involved analyzing the impact of interventions on DFW rates, on General Education Core learning outcomes, and providing recommendations to the university regarding future directions for the gateway courses and broader implications for undergraduate courses. As outlined in an internal Quality Enhancement Plan impact report, three germane initiatives were identified through completion of the G2C program. These were common for all five gateway courses: 1) faculty development, 2) Learning Assistants (LAs) to provide peer-to-peer instruction and 3) large-enrollment active learning spaces.

Association of College and University Educators (ACUE)

The Association of College and University Educators (ACUE), founded in 2014, offers evidence-based courses in effective teaching practices based on an Effective Practice Framework developed in conjunction with the American Council on Education (MacCormack et. al., 2018). The Center for Faculty Development at USM offers faculty the opportunity to complete three, ten-week courses to obtain certification in effective active learning pedagogy. Upon completion of these ACUE courses and being awarded certification in effective college instruction (Appendix A), BSC 110, the first course in a two-semester series of foundational biological sciences courses, sections taught by the researcher were converted from a traditional course design, utilizing an instructor-centered didactic lecture approach, to an active learning class design supported by peer-assisted instruction utilizing undergraduate Learning Assistants.

Flipped Classroom Model

Active Learning (AL) takes many forms and has many descriptions but classically it is defined as employing “instructional activities involving students in doing things and thinking about what they are doing” (Bonwell & Eison, 1991). These activities may require students to interact with each other and/or instructors to solve problems, complete tasks, or participate in Socratic discussions. The course redesign employed by the researcher for Biological Sciences I (BSC 110) involved a switch to a “flipped “or “inverted” learning environment with recorded lectures to be viewed online by students independently before class, and time in a class dedicated to student collaborations and completion of various activities. As with AL, the flipped classroom has been described in various ways within the literature. However, Bergmann and Sams (2012), considered by many to have pioneered the implementation of the design, offer the following description of a flipped classroom: “that which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class” (p. 13). This course design requires a high degree of self-directed learning since it requires a commitment from students to review materials and prepare before class. There is a significant body of research exploring the efficacy of AL in improving student performance and persistence (Abeysekera & Dawson 2015; Bishop & Verleger 2013;

Butt 2014; Freeman et al., 2024; Freeman, Haak & Wenderoth, 2011; Reyneke & Fletcher, 2014), but there is far less empirical data supporting the positive impact of a flipped classroom design on student outcomes and persistence (Brame, 2013). Flipped classroom studies typically focus on student perceptions of the design rather than assessing course outcomes (Langin et al., 2020). Moreover, when studies do assess course outcomes, there are inconsistent results, and many studies are limited to a single cohort or small sample sizes which may inflate effect size (Langin et al., 2020).

A flipped classroom model can be challenging to implement effectively in large enrollment courses, especially one with a diverse student population with varying levels of preparedness, yet this type of intervention is very likely just the type of learner-centered environment required to reduce achievement gaps observed in these types of courses. Haak et al. (2011) report that more traditional efforts to reduce these gaps, such as increased resources that may be dependent on temporary funding, tend to have benefits that are disproportionate to underrepresented or disadvantaged student populations. Conversely, they propose the “Carnegie Hall hypothesis” suggesting that an AL class provides an opportunity for students to repetitively practice applying information thereby, encouraging the development of the critical thinking skills regardless of their background or previous exposure to activities/assessments requiring higher-order cognitive skills (Haak et al., 2011).

Learning Assistant Model

In 2003, the Colorado Learning Assistance (LA) Program was launched at the University of Colorado Boulder in an effort to improve the outcomes for students in Science, Technology, Engineering, and Math (STEM) fields. Consequently, there is a growing movement involving the use of peer LAs, with over 100 institutions of higher learning currently utilizing an LA program (Learning Assistance Alliance, 2021). The Learning Assistance Alliance (2021) defines LAs as “undergraduate students who, through the guidance of weekly preparation sessions and a pedagogy course, facilitate discussions among groups of students in a variety of classroom settings that encourage active engagement.” Something that distinguishes LAs from other undergraduate tutors or Teaching Assistants is that they are trained in pedagogical techniques, to provide support for students when completing activities, lead small group discussions, encourage student collaborations, and foster higher-order thinking (Otero et al., 2006; Learning Assistant Alliance, 2021). Research has indicated improved student outcomes in a variety of undergraduate STEM courses where LAs are leveraged to lower the student to instructor ratio and facilitate the implementation of an active and cooperative learning environment (Learning Assistant Alliance, 2021). Sellami et al. (2017) reported that the use of LAs resulted in an increase in student performance on exam questions requiring higher-order cognitive skills. Furthermore, increases in student performance and decreases in DFW rates are most pronounced in minority student groups providing potential for reducing the achievement gap (Van Dusen & Nissen, 2020).

Statement of the Problem

Flipped classroom designs have been utilized for many years and the resulting influences on student perceptions and course outcomes have been widely investigated. However, there is a lack of empirical evidence sufficiently robust enough to support many of the assertions that a flipped classroom model results in improved student performance. Much of the published research is limited to data from a single study or synthesis reviews involving findings from multiple studies. There is a gap in the literature comparing student performance and persistence between flipped and traditional instructional models in large-enrollment science courses and on the efficacy of a flipped classroom in closing achievement gaps for students from marginalized populations.

Theoretical Framework

Constructivism

Instruction through inquiry is deeply rooted in educational theories of constructivism. Constructivist theories contend that individuals gain knowledge through real-life experiences and learn best when presented with real-world problems to solve. Constructivists like Jean Piaget, John Dewey, and Lev Vygotsky maintain that learning is more meaningful when it is constructed by the student (Matthews, 2003). However, while Dewey and Piaget focused on the importance of an individual's role in the active construction of knowledge and the processes involved in knowledge construction (Dewey,1998; Piaget, 1953), Vygotsky's teachings drew attention to the importance of social aspects of learning environments (Vygotsky, 1962). An instructor's role in constructivism is to facilitate students' progression through the levels of cognitive development and understanding. Metacognition, which has strong ties to ideals of constructivism, refers to an individual's knowledge and awareness of their own thinking and learning processes. Dewey contended that individuals learn more from reflecting on experiences than from their participation in the experiences themselves (Tanner, 2012).

Cognitive Load Theory

Cognitive Load Theory, as described by Sweller (1994), explains the difficulty surrounding learning new material in terms of putting too much material into the working memory. If this exceeds the capacity of the working memory, it will inhibit an individual's ability to process the information properly. This theory distinguishes between the intrinsic, interaction of elements of useful information, and extrinsic, extra information provided in context. When too much information is presented that must be processed simultaneously, an individual's intrinsic cognitive load is increased to a level that makes learning difficult (Abeysekera & Dawson, 2014).

Conceptual Framework

Active Learning and Cooperative Learning

First introduced in the early 1990s by Johnson, Johnson, and Holubec (1993), cooperative learning involves students working in small groups to maximize their own learning as well as the learning of the other members of the group. Active learning and cooperative learning put into practice the various aspects of student-centered learning theories (constructivism). Through cooperative learning, social interactions, and interactions with a mentor or peer, students can accomplish more than they are able to as individuals. Additionally, working in groups to discuss course content, solve problems and complete tasks provides a translation of the concept of metacognition into an instructional application. Relocating lectures (extrinsic cognitive load) outside of class through a flipped classroom design should allow students time to process this information in class reducing the intrinsic cognitive load and improving student learning outcomes (Turan & Goktas , 2016; Abeysekera & Dawson, 2014). An active learning classroom, where individuals are allowed to question what they know or do not know encourages students to be metacognitive and leads to more intentional learning and a more meaningful learning experience (Brame, 2013).

Purpose of Study

The primary goal of the study was to assess the efficacy of pedagogical interventions involving a flipped classroom design and the incorporation of Learning Assistants at increasing student success in a high enrollment, introductory-level biology course.

Justification

The Undergraduate STEM Education Initiative proposed by the Association of American Universities (2017) outlined the need to "influence the culture of STEM departments at AAU institutions so that faculty members are encouraged and supported to use teaching practices proven by research to be effective in engaging students in STEM education and in helping students learn" (p. 4). The results of this study should prove useful in informing future curricular decisions at the university. Additional proposed benefits include increasing the knowledge base for commonly used pedagogical elements and providing guidance to educators contemplating undertaking a new course design or course redesign in STEM fields.

Research Questions and Hypotheses

Overarching Research Questions: Is there a significant interaction effect between course design (traditional vs. flipped course design) and academic success (exam score means and DFW rates)? To what extent do specific demographic factors of a student population impact the effectiveness of this pedagogical intervention on academic success? Does this pedagogical intervention influence students' assessment of their learning gains?

Specific Research Question One: Is there a statistically significant difference in academic success in the course sections taught with a flipped class design versus the traditional class design sections?

Null Hypothesis One (H_0-1): Academic success, as measured by course section exam score means, is the same in sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and sections with traditional didactic instruction.

Specific Research Question Two: Is there a statistically significant difference in the DFW rates in the flipped class sections versus the traditional class sections?

Null Hypothesis Two (H_0-2): Academic success, as measured by DFW rates, is the same in sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and sections with traditional didactic instruction.

Specific Research Question Three: Is there a statistically significant difference, when controlling for ethnicity, Pell grant status, and first-generation status, in the DFW rates in the flipped class sections versus the traditional class sections?

Null Hypothesis Three (H_0-3): The DFW rates, after controlling for ethnicity, Pell grant eligibility, and first-generation status, are the same for class sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and class sections with traditional didactic instruction.

Research Question Four: How has the redesign to a flipped classroom model with the addition of active learning facilitated by peer Learning Assistants influenced how students assessed their own learning, as measured by a customized Student Assessment of Learning Gains (SALG) survey?

Null Hypothesis Four (H_0-4): Student assessment of their own learning, as measured by a customized Student Assessment of Learning Gains (SALG) survey, is the same for class sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and class sections with traditional didactic instruction.

Assumptions

- The research assumes all participants answered all survey questions thoughtfully and truthfully.
- All classes included in the study were assumed to be demographically similar representing equal groups.

Delimitations

- Data were collected from a convenience sample within eight BSC 110 classes taught at USM by the researcher over eight semesters from the fall of 2015 to the spring of 2018.

Limitations

- The study is limited to one specific introductory biological sciences course taught by a single instructor which may reduce the generalization of the study.
- A quasi- experimental study design was utilized as assignment of study participants into control or experimental groups was not truly random. This creates a possibility for non-equal groups which may lower internal validity (Tuckman & Harper, 2012).
- The introduction of the LAs simultaneously with the shift to an active learning, flipped class design makes it impossible to disentangle the effects of the two interventions on student performance and persistence.

CHAPTER II – LITERATURE REVIEW

Introduction

A learning theory provides insight into how students learn but does not provide parameters for the development of instructional methods. Instructors should utilize theoretical frameworks in curricular design, but pedagogical practices must be grounded in evidence-based "best practices" and not in theory alone (Duran & Duran, 2004). A common method employed in higher education to make the connection between theories of constructivism and practice is a blended learning approach. This involves face-to-face instructor-guided inquiry in conjunction with out-of-class, self-directed assimilation of knowledge. A form of blended learning called the flipped or inverted model of instruction is becoming increasingly prevalent in higher education (O'Flaherty & Phillips, 2015). The Cognitive Load theory introduces concepts of intrinsic and extrinsic cognitive load and suggests that when too many new elements are introduced into the working memory it may reduce an individual's capacity to effectively process and comprehend the new information (Sweller, 1994). A flipped classroom may reduce the cognitive load by allowing time for individuals to process information before class thereby improving learning outcomes and encouraging mastery (Turan & Goktas (2016). Cooperative learning may result in a collective working memory effect creating a situation where social interactions may fill in gaps in knowledge and preparedness for other group members thereby reducing the collective cognitive load (Sweller, Van Merriënboer, & Paas, 2019). However, this type of instructional design can be a challenge to effectively implement in large-enrollment classes. The implementation of a Learning Assistant model, leveraging undergraduates previously successful at completing the course for peer-to-peer instruction, provides a potential solution to this problem (Otero et al., 2006). Research has shown that courses implementing a Learning Assistant model improve student performance, especially for continually marginalized populations (Van Dusen, & Nissien, 2020).

Theoretical Framework

Constructivist Theory

The 2009 Vision and Change in Undergraduate Biology report calls for a shift to a student-centered learning model of instruction. While the Vision and Change report does not provide an explicit definition of what constitutes a student-centered classroom, it describes this type of environment as “interactive, inquiry-driven, cooperative, collaborative, and relevant” (AAAS, 2009). If one delves into the history of science education, it is quickly obvious that this type of educational reform has been promoted since the 18th century. Rousseau and Pestalozzi valued experience over book learning and favored active investigation over memorization. This influenced the ideals of Froebel who encouraged active, cooperative learning and suggested first-hand experiences should form the basis for education. Herbert advocated for organizing content into conceptual schemes to prompt students to make connections between ideas while Huxley argued for a curriculum heavily invested in scientific inquiry (Bybee & DeBoer, 1994). The Progressive Education Movement of the 20th century marked a period of confirmation of child-centered education, the importance of real-world applications, the social importance of knowledge, and the need to make learning enjoyable and meaningful. Dewey applied a pragmatic philosophy to the development of a process-focused science curriculum. He contended that the process was as important, if not more so than scientific knowledge. He believed that experimentation was the psychological link between experience and knowledge. He promoted the concept of a democratic classroom where teachers did not hold a dictatorial role and students were given an active voice. Dewey rejected the concept of students as passive recipients of knowledge asserting that education is only truly effective when learning is linked to current knowledge and prior experiences (Bybee & DeBoer, 1994). Craig was influential in shifting the existing model of the American science curriculum from knowledge of facts to principles and generalizations. He was a proponent of scientific principles and methods as goals of instruction with the use of experiences, activities, and inquiry as a means of mastery (Bybee & DeBoer, 1994). Jean Piaget, through his research in developmental psychology on how children learn, provided evidence to support the need for more student-centered, active learning environments. He concluded that individuals construct knowledge as they pass through a series of predictable stages from low, less powerful means to higher, more powerful ones. Progression through the stages is based on maturity, physical and social activities, and the development or modification of existing schemata to accommodate added information and establish cognitive equilibrium (Powell & Kalina, 2009). Conversely, Lv Vygotsky believed learning was continuous with no discernible stages. He stressed that language and reasoning developed through social interaction and that an individual’s culture provided a means of thinking. He proposed a Zone of Proximal Development wherein, through cooperative learning and scaffolding, an individual could accomplish much more through interaction with a mentor or peer than they could on their own. This essentially describes the role of a teacher (Powell & Kalina, 2009). In The Process of Education (1977), Bruner proposed that any child could be taught any subject at any age assuming material was presented at the appropriate level. Bruner (1977) advocated for a spiral curriculum approach and contended “A curriculum as it develops should revisit the basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them” (pg. 13).

Constructivist Learning Theory calls for moving away from traditional, didactic, teacher-centered instruction toward more active, student-centered models (Youyan & Lau, 2010). Constructivist Learning Theory, based in part on the ideals of Piaget and Vygotsky, dictates that learning is not the passive reception of knowledge but embodies an active process of constructing meaningful knowledge through individual experiences, prior knowledge, and peer interactions (Slavin, 2006). In terms of education, there are two major forms of constructivism: cognitive constructivism built on the ideals of Piaget and social constructivism influenced by the research of Vygotsky. Collectively, a constructivist approach to learning is truly student-centered promoting interactions with others and society and drawing on prior knowledge and experiences to construct learning (Powell & Kalina, 2009). The student is considered an independent thinker not just a submissive receiver of information from which only a reiteration of facts and ideas is required to demonstrate learning. The teacher functions as a “facilitator of learning” not as a content expert who merely broadcasts information. Learning in the constructivist classroom allows for the development of proficiencies, not solely through the development of factual knowledge, through but the collaborative completion of tasks. This type of student-centric model improves students' cognitive skills and enhances their motivation to learn both of which are major contributors to learning and overall academic performance (Singer and Moscovici, 2008).

Metacognition

The original Bloom Taxonomy provided a hierarchical ranking of educational objectives in a pyramid style with knowledge and comprehension making up the base. Application, analysis, synthesis, and evaluation represent higher-order thinking toward the top of the pyramid. Students are expected to progress through the lower levels by utilizing the simpler skills of memorization and understanding to the development of the higher-order thinking skills to apply content knowledge, create novel products, and assess the value and purpose of knowledge (Bloom, 1956). While the first manifestation of this learning objective taxonomy acknowledged the categories of facts, concepts, and procedures, updated versions include metacognition (Krathwohl, 2002). One of the key findings reported by Bransford, Brown, & Cocking (2000) is the efficacy of a "'metacognitive' approach to instruction" (p. 18) which demands individuals "externalize mental events" (p. 67). Therefore, it seems reasonable to assert that educational strategies like active learning and cooperative learning that integrate theory and practice need to consider the involvement and reflection of students in their own learning process.

Improving undergraduate science education is of high concern and Active Learning strategies are a commonly employed approach. The 2009 Vision and Change in Undergraduate Biology strongly suggests the implementation of Active Learning pedagogies but makes no references to metacognition. In 2011, the updated Vision and Change report stressed the importance of understanding the processes of thinking, aka metacognition (AAAS, 2011). This suggests a pedagogical shift in acknowledging the importance of being transparent and intentional with students about learning strategies and processes. Students should not only know what they are expected to do but why they are expected to do it. John Flavell (1979) argued the following:

> Metacognitive knowledge consists primarily of knowledge or beliefs about what factors or variables act and interact in what ways to affect the course and outcome of cognitive enterprises. There are three major categories of these factors or variables—person, task, and strategy. The person category encompasses everything that you could come to believe about the nature of yourself and other people as cognitive processors.…… some cognitive enterprises are more demanding and difficult than others, even given the same available information. For example, it is easier to recall the gist of a story than its exact wording……. there is a great deal of knowledge that could be acquired concerning what strategies are likely to be effective in achieving what subgoals and goals in what sorts of cognitive undertakings……. it is possible to acquire metacognitive strategies as well as cognitive ones……. metacognitive experiences can affect your metacognitive knowledge base by adding to it, deleting from it, or revising it. You can observe relationships among goals, means, metacognitive experiences, and task outcomes and—Piagetian fashion—assimilate these observations to your existing metacognitive knowledge and accommodate the knowledge to the observations. (pp. 907-908)

Since its introduction to the field of education, metacognition has been defined in a variety of discipline-specific ways. Tanner (2012) suggests this may be due to the lack of a well-defined explanation of what is considered active learning and to what degree metacognition is considered in its design and implementation. One can incorporate metacognition into a classroom design by allowing the opportunity for recognizing points of confusion and "ask students what they find confusing, acknowledge the difficulties" as well as "model the thinking processes involved in your field and sought in your course by being explicit about "how you start, how you decide what to do first and then next, how you check your work, how you know when you are done" (Tanner, 2012, p. 118). In the extensive research anthology How People Learn, Bransford, Brown, & Cocking (2000) define metacognition as the ability of an individual to both predict how well they will be able to complete tasks and to self-assess their degree of mastery. Additionally, they assert that "teaching practices congruent with a metacognitive approach to learning focus on sense-making, self-assessment, and reflection on what needs improvement" (p. 12). Furthermore, Bransford, Brown, & Cocking (2000) report that research indicates metacognitive approaches to learning favor the transfer of skills and that "transfer is affected by the degree to which people learn with understanding rather than merely memorizing a set of facts or follow a fixed set of procedures" (p. 55). Krathwohl (2002) states theories of education, regardless of origin or specific constraints, and research into learning historically have centralized around helping students understand their personal learning processes which subsequently increases overall learning gains.

Cognitive Load Theory

Information can be thought of as elements contained within cognitive constructs referred to as schema which can be altered when new information is presented and determine how that new information is processed. The capacity of an individual's working memory is greatly limited. Schema effectively groups various pieces of information into singular rational groups to increase the amount of information that can be maintained within the working memory (Sweller, 1994). When new information is assimilated, it requires time for processing and the development novel schema. It may be quite some time before automatic processing, the application of a schema to a concept without conscious thought, allowing for an individual's working memory to be dedicated to a new task (Sweller, 1994). Cognitive Load Theory (CTL) is based on the idea that if the working memory is limited, introducing too much information which must be processed simultaneously to complete a task, will inhibit an individual's capacity to learn. The goal of learning under the constructs of CTL "is the construction and subsequent automation of schemas" and to utilize appropriate instructional designs that "stimulate and guide students to engage in schema construction and automation" (De Jong, 2010, p. 109). There is a growing body of research indicating automation can be achieved through the use of instructional designs that seek to not overload the working memory thereby increasing the likelihood of successfully completing tasks and developing mastery of content (Sweller, 1994; Clark, Nguyen, & Sweller, 2006; De Jong, 2010).

According to the tenets of CLT, when presented with information to learn there are three basic forms of load individuals experience: intrinsic (characteristics of what is to be learned), extrinsic (how the information to be learned is presented), and germane (load created by the learning process) (De Jong, 2010). It is believed that intrinsic load related to the difficulty of the information presented cannot be reduced by instructional design, but it may be influenced by prior knowledge as this decreases the cognitive exertion required to recall the information (Van Merriënboer & Sweller, 2006). Effective instructional design can reduce the extrinsic load, and due to an assumed additive effect between intrinsic and extrinsic loads, ultimately lead to a relatively higher germane load thereby resulting in effective learning (Sweller, Van Merriënboer, & Paas, 2019). De Jong (2010) emphasizes “The three main recommendations that come from cognitive load theory are: present material that aligns with the prior knowledge of the learner (intrinsic load), avoid non-essential and confusing information (extraneous load), and stimulate processes that lead to conceptually rich and deep knowledge (germane load)” (p. 126).

De Jong (2010) advises there are numerous sources of extrinsic load, induced by introducing material not essential to the construction of relevant schema, but that this extraneous load may be reduced by employing an effective instructional design. Bransford, Brown, & Cocking (2000) contend some learners require adequate time to delve into and explore concepts in order to make necessary connections and that this, in conjunction with reducing the pace at which new information is introduced, increases learning. Adding too much new information (too many elements) into the working memory will tax it beyond its capacity (high load) and this may lead to reductions in an individual’s ability to process the information and produce a new schema. It has been proposed that moving instructional materials out of class will reduce the extraneous load on the working memory and promote more efficient learning (Sweller, 1994). De Jong (2010) suggests that “the ‘‘split-attention’’ effect, for instance, refers to the separate presentation of domain elements that require simultaneous processing” (p. 108). One of the cognitive load instructional principles proposed by Clark, Nquyen and Sweller (2006) indicates the separation of knowledge and processes for effective learning. The flipped classroom instructional design has been supported by empirical research to reduce the strains on cognitive load. This may be particularly beneficial in large enrollment courses with a diverse student population due to the allowance for self-pacing through the pre-class preparatory material (Clark, Nguyen, & Sweller, 2006). Turan and Goktas (2016) reported that "when a flipped classroom method is used effectively, it can lower students' cognitive loads and affect their learning in a positive way" (p. 58).

Conceptual Theory

Flipped Classroom Design

According to extensive research conducted by the National Research Council (Bransford, Brown & Cocking, 2000), It is vital that student-centered learning environments be designed in such a way as to ensure learning with understanding. This type of environment builds on the "conceptual and cultural knowledge" students arrive with (Bransford, Brown & Cocking, 2000, p. *134).* Students are not only required to memorize or regurgitate information but to analyze, make predictions and explain their reasoning. This provides the opportunity for students to construct knowledge by building on existing knowledge in a manner that is both gradual and highly structured. However, students must also acquire knowledge and skills, so to some degree, the environment must also be knowledge centered. Unfortunately, curricula in science often focus more on learning facts than on "doing science" which is not conducive to learning for understanding (Bransford, Brown & Cocking, 2000, p. *136).* Bretzmann (2013) contends it is appropriate to consider a flipped classroom as a process. This type of pedagogical intervention would allow for the assimilation of knowledge but also encourage the focus on the process of how that knowledge was amassed (Findlay-Thompson & Mombourquette, 2014).

There are various definitions used to describe the flipped or inverted classroom model. A simple and frequently cited definition states that inversion indicates activities typically carried out in the classroom are now completed outside the classroom and those typically completed independently are not carried out in the classroom (Lage, Platt, and Treglia, 2000). However, it is highly variable as to what constitutes typical in-class and out-of-class components for this type of course design. Research supports that employing a flipped classroom model results in increased student satisfaction with the course and teacher, increased academic performance, and increased class attendance (O'Flaherty and Phillips, 2015). Additionally, blended instruction, such as a flipped classroom, is reported to be more effective than face-to-face or online instruction individually (U.S. Department of Education, 2010).

Recorded lectures viewed outside of class allow students to pause and review points of confusion and to take notes at their own pace allowing for better comprehension of course material. Self-pacing may be a strong contributor to improvements in student achievement (Kurt, 2017). It is the contention of Bishop and Vergler (2013) that presenting course content before class allows students time to consider, research and reflect reserving time spent in class for practice and skill development. According to Caviglia-Harris (2016), students ranked the online lecture videos as the most useful aspect of the flipped classroom. A flipped class allows for scaffolding and more directed instruction by reducing time limits for instruction and providing options for self-pacing. One of the multiple prepositions asserted by Abeysekera and Dawson (2014) related to employing a flipped classroom states “Student self-pacing of pre-recorded lectures may reduce cognitive load and help learning in a flipped classroom environment” (Abeysekera & Dawson, 2014, p.9). Seery & Donnely (2012) also reported decreased cognitive load related to the use of pre-recorded videos as a pre-class instructional tool. Turan & Goktas (2016) contend that cognitive load can be lowered and learning positively affected through the effective use of a flipped classroom model.

Additional factors that may reduce cognitive load are more readily available instructional guidance and increased peer-peer interactions (Moreno, 2004; Artino, 2008). The traditional classroom model for each study dedicated most of the face-to-face meetings to instructor-led lectures with little time for activities or collaboration. Even in the absence of any discernible increases in summative-based student performance, Ojennus (2015) states that surveyed students from the flipped classroom intervention reported having greater confidence in working with others and in tackling complex concepts. Extensive peer-peer interactions, coupled with constant and immediate feedback from peers and an instructor, increase the self-efficacy and confidence of learners (Kurt, 2017). Self-directed learning required for the flipped classroom model also likely increases self-efficacy. There is agreement among the various constructivist theorist that the construction of learning is an active process carried out by the student. The more process-driven models assert that learning is “self-directed”, and students are adept enough to undertake their own learning (Green & Gredler, 2002). While self-efficacy is developed in various ways, one of the most efficient ways is through “mastery experiences” (Bandura, 1994). These types of experiences correspond to previous task-related successes that result in an increased belief in learning ability (Partin et al, 2011).

The flipped classroom model, requiring self-directed out-of-class learning and in-class completion of practice-based activities, may increase student performance over a traditional classroom due in part to increased self-efficacy.

Cooperative Learning

Cooperative learning leverages small groups to facilitate students achieving learning goals, both as individuals and as a group. A flipped classroom design allows for maximum class time to be dedicated to this form of active learning. Erbil (2020) contends that both instructional techniques have a basis in constructivism, specifically the social constructivist ideas of Vygotsky, and have been proven most effective at increasing student success and positively influencing attitudes when used in tandem. When used together, students review instructor-generated content individually and then work within small groups in class to complete tasks related to that content. This fits with Vygotsky's Zone of Proximal Development where the learning gains of individuals will be greater through interactions with more knowledgeable peers within the group than if those students were working independently (Erbil, 2020). This type of peer-to-peer interaction represents a form of scaffolding, learner support techniques designed to increase learning gains. Sabel (2020) puts forth that when deciding on appropriate scaffolds it must be remembered that there exists a vast range of preparedness within student populations toward learning processes, such as metacognitive behavior, and reaching a deeper understanding of content may require repetitive exposure.

The collective working memory effect is supported by both the Zone of Proximal Development and Cognitive Load Theory. It explores the concept of shared working memory between members of a collaborative group creating a situation where social interactions may fill in gaps in knowledge and preparedness for other group members thereby reducing the collective cognitive load (Sweller, Van Merriënboer, & Paas, 2019). Lord (2001) reported a statistically significant increase in learning gains as well as increased student excitement for content in a biology course utilizing cooperative learning. Research also shows that collaborative learning leads to higher engagement from students and provides opportunities for peer-assisted learning reducing the need for rigorous interactions with a course instructor (Lord, 2001). Additionally, students recognize collaborative learning resulted in a decrease in academic anxiety as confidence in course content increased through interactions with peers who were able to provide less expert, relatable explanations of material (Cooper, Downing, & Brownell, 2018).

The role of collaborative learning was explored by Tinto (1997) in relation to the process of students leaving higher learning. It was reported that the academic groups that were formed often spilled over into the other aspects of a student's experiences outside the classroom. New students may find themselves able to merge academic and social needs through these cooperative learning opportunities. Students were exposed to many points of view and beliefs other than just the instructor and were able to contribute their own personal experiences to the group dynamic creating a much deeper learning experience (Tinto, 1997). There is a direct correlation between the learning gains of students who participate in active learning and the confidence they feel toward their understanding of course material. This has been shown to allow for less time studying/preparing for course assignments and more time for social activities and campus engagement. Therefore, there may be an indirect connection between the positive social aspect of collaborative learning and the decisions made by students to persist or depart an institution (Braxton, Milem, & Sullivan, 2000).

Learning Assistant Model

There is a growing body of research to support the use of active learning pedagogy within STEM disciplines to increase student learning outcomes (Freeman et al. 2014). Cooperative and active learning environments are shown to reduce disparities observed for continually marginalized student populations (Theobald et al., 2020). However, this type of instructional design can be a challenge to effectively implement in large-enrollment classes. The implementation of a Learning Assistant model, leveraging undergraduates previously successful at completing the course for peer-to-peer instruction, provides a potential solution to this problem (Otero et al., 2006). The Learning Assistant (LA) program was first introduced at the University of Colorado Boulder (CU-Boulder) in 2001. It was initially a small program with eight LAs all working within a single department. Over the last two decades, the program has grown and been implemented worldwide with close to 100 LA programs within approximately 300 departments in STEM fields utilizing over 1000 LAs (Top, Schoonraad, & Otero, 2018). A Learning Assistant is a paid position where undergraduate students in STEM fields are hired to allow faculty to implement more student-centered STEM course designs. The utilization of LAs in large-enrollment courses reduces the student-instructor ratio and may allow for greater engagement by students in active learning (Hernandez et al., 2021). In addition to the facilitation of learning in what are typically large-enrollment, gateway courses, the LA program works to recruit individuals into careers of teaching within STEM fields (Top, Schoonraad, & Otero, 2018). According to the work of Webb, Stade, and Graver (2014), there are four main goals of implementing an AL program: improvement in education quality within specific courses, creating a culture advocating for research-based instructional design, recruiting, and preparing future teachers within STEM fields and the inclusion of current faculty in these efforts.

With the implementation of LA programs on such a large scale, there are many different specific methods for its implementation. However, Top, Schoonraad, & Otero (2018) assert it should include the following essential components: LAs should participate in a pedagogy course, meet weekly with faculty to prepare for the classes they assist with, and work within those classes to facilitate interactions within student groups. The pedagogical training that LAs receive is one of the main things differentiating them from tutors and individuals offering Supplemental Instruction. As reported by Top, Schoonraad, & Otero (2018):

> The pedagogy course introduces LAs to the educational research literature, learning theory, and strategies that support eliciting student ideas within STEM disciplines and using these ideas to guide questioning and actions that can help individuals in groups work together to make sense of a topic. The pedagogy course also addresses topics such as building relationships with students, mindset, metacognition, and differentiation.… Although not all LAs intend to become teachers, the program is designed to help them learn effective practice through their LA experience. (p.2)

Additionally, LAs work within the classroom rather than outside class and work to not only assist in the comprehension of course content but the development of higher-order thinking and making connections (Hernandez et al., 2021; Alzen, Langdon, & Otero, 2018). It is the contention of Alzen, Langdon, & Otero (2018) that "the design of the LA program at large are aimed at making a difference in the ways students think and learn in college overall and not just in specific courses" and that they "expect exposure to the program to influence student success in college generally" (p.2). Through their participation in the weekly course prep meetings with faculty, the LAs not only delve into the course material and develop a deeper understanding of it themselves but work to analyze how students are participating in their learning of the material and how to have a positive impact on their efforts (Otero, 2006). Therefore, the design of the LA program allows for increased learning for not just the students, but the LAs and potentially faculty as well (Alzen, Langdon, & Otero, 2018). There is evidence to support increases in positive student outcomes, but also deeper content comprehension for the LAs with a 10% increase reported for LAs, related to non-LA peers persisting to degree completion (Top, Schoonraad, & Otero, 2018).

At the flagship school, the University of Colorado Boulder, researchers credit the LA program with substantive improvements in both teaching and learning as well as the culture within the STEM fields through the increased ability to provide active learning environments for students (Webb, Stade, & Grover, 2014). Hernadez et al. (2021) report that improvements to student learning outcomes are not the only benefit to interactions between students and LAs, but that there are multiple social supports conveyed to students as well. This suggests the cognitive and social training in the processes of thinking LAs receive as part of the pedagogy course facilitates a level of comfort and support students need to accept the role of mistakes in learning and promote the development of a growth mindset (Hernadez et al., 2021). Webb, Stade & Grover (2014) testify that calculus courses at the University of Colorado Boulder had a predictable DFW rate of greater than 30%, but the implementation of the LA program saw this significantly reduced. Perhaps more noteworthy was the equivalency of this decline in the DFW rate across gender and ethnic categories. Research reported by Top, Schoonraad and Otero (2018) reveals that rates of course success, as defined by earning a grade of C or higher, increased by 10% and that participating in as little as one LA facilitated course increased student persistence toward degree completion. Again, a noteworthy point is that the increase in persistence was even greater (almost 10% higher) for first-generation students.

Unless variables such as gender, race, and first-generation status are controlled for, the positive influence of an LA program on student success and persistence may be considerably undervalued (Alzen, Langdon, & Otero, 2018). Benford and Gess-Newsome (2006) conducted an extensive analysis of the DFW rates in STEM courses at Northern Arizona University where they discovered that African Americans had rates almost twice that of their white peers (40% vs. 22%, respectively). Research into DFW rates in an LA-supported introductory physics course known to be unduly difficult for marginalized populations revealed that DFW rates decreased overall, but those decreases were much more pronounced for African Americans and Indigenous peoples (Van Dusen & Nissien, 2020). After exploring achievement gaps in the same type of physics classes, Van Dusen, White, & Roualdes (2016) found that students considered non-dominate with respect to race and level of preparedness not only displayed increased learning outcomes in LA-supported classes but outperformed their dominant peers. Contributions by Alzen, Langdon, & Otero (2018) increase the mounting evidence that not only are performance gaps between marginalized students and their contemporaries reduced in LA-supported STEM courses, but this increase in performance levels may continue in future courses. These extraordinary outcomes in the face of historically and continually persistent achievement gaps may be due in part to changes in the classroom community dynamics resulting from the presence of LAs. Students who previously felt ostracized or excluded are encouraged to contribute to the learning process and share experiences (Van Dusen, White, & Roualdes, 2016). Students may view an LA as a less intimidating community partner and be more likely to communicate their thoughts and experiences with them than with the course instructor (Alzen, Langdon, & Otero, 2018). When students are able to increase their learning outcomes, they are more likely to persist. Therefore, LA programs likely contribute to increased student retention and changes at an institutional level that may result in the development of more inclusive and equitable learning environments.

Deficiencies in the Literature

There is a lack of empirical evidence sufficiently robust enough to support declarations that a flipped classroom model consistently results in improved student performance. Most of the published research is limited to data from a single study or synthesis reviews involving findings from multiple studies. Therefore, more research is needed to provide sufficient experimental evidence to support claims that the utilization of a flipped classroom model results in substantial enhancement of academic performance (O'Flaherty & Phillips, 2015). It is true that there is a growing body of research exploring the flipped classroom approach, particularly in terms of increased academic achievement. However, reviews of the literature show a lack of adequate exploration into the specific methodology and theories supporting this pedagogical design, in addition to inconsistent findings as to the positive or negative influence of this design on student performance (Ash, 2012; Chen et al., 2014; Hung, 2015). Studies also indicate a need for further research that quantifies the impact of flipped classrooms on student outcomes (Berrett, 2012; Bishop & Verleger, 2013). There is also a lack of research available that breaks down the efficacy of a flipped classroom design at improving persistence in science courses for historically and continually marginalized student populations within STEM fields. This may be due to difficulties in obtaining large enough samples to provide enough statistical power to adequately disaggregate data due to the underrepresentation of these student populations in STEM courses (Van Dusen, & Nissien, 2020).

CHAPTER III - METHODOLOGY

A quasi-experimental intervention study was completed to assess the efficacy of an active learning design, as compared to traditional didactic instruction at improving student success in an introductory-level biology course. The active learning intervention involved the implementation of a flipped classroom model with the addition of active learning experiences facilitated by peer Learning Assistants. Archived data from eight previous semesters were collected for analysis. Data were collected from four semesters where the class was taught using a traditional approach, then for four more semesters after an active learning intervention was implemented. Students both in traditional lecture classes and the intervention classes were taught by the same instructor. Course content and lecture materials for all classes varied only minimally.

Research Questions and Hypotheses

Research Question One: Is there a statistically significant difference in academic success in the course sections taught with a flipped class design versus the traditional class design sections?

Null Hypothesis One (H_0-1): Academic success, as measured by course section exam score means, is the same in sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and sections with traditional didactic instruction.

Research Question Two: Is there a statistically significant difference in the DFW rates in the flipped class sections versus the traditional class sections?

Null Hypothesis Two (H_0-2): Academic success, as measured by DFW rates, is the same in sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and sections with traditional didactic instruction.

Research Question Three: Is there a statistically significant difference, when controlling for ethnicity, Pell grant status, and first-generation status, in the DFW rates in the flipped class sections versus the traditional class sections?

Null Hypothesis Three (H_0-3): The DFW rates, after controlling for ethnicity, Pell grant eligibility, and first-generation status, are the same for class sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and class sections with traditional didactic instruction.

Research Question Four: How has the redesign to a flipped classroom model with the addition of active learning facilitated by peer Learning Assistants influenced how students assessed their own learning, as measured by a customized Student Assessment of Learning Gains (SALG) survey?

Null Hypothesis Four (H_0-4): Student assessment of their own learning, as measured by a customized Student Assessment of Learning Gains (SALG) survey, is the same for class sections utilizing a flipped classroom with active learning facilitated by peer Learning Assistants and class sections with traditional didactic instruction.

Study Design

Study Participants

The university in which this research was conducted is designated as a Carnegie R1 research institution and is located in the southeastern region of the US. According to institutional statistics from fall 2020, the university has an annual enrollment of just over

11,000 undergraduate students. The university's undergraduate population is approximately 63% white, 30% Black or African American, and 7% reported as other ethnicities. Roughly 30% of the undergraduate students identify as first-generation, which USM defines as a student for whom neither parent has completed a four-year degree at an institution within the US. Over 80% of students receive grants or loans to assist with educational expenses. Within the School of Biological, Environmental, and Earth Sciences, there are around 600 students majoring in the biological sciences.

Participants of the study included students enrolled in sections, all taught by the researcher, of the first course in a two-semester series of foundational biological sciences courses. While the courses are designed for Biological Sciences majors, there is typically a diverse student population since many students take the course to meet the General Education Science Laboratory course requirement. The researcher has over 20 years of experience teaching undergraduate courses and has taught BSC 110 consistently for 17 years. Additionally, the researcher has extensive training in research-based active learning pedagogy. The study was a quasi-experimental intervention with a control group and an experimental group into which students were placed through a registration process and therefore not truly randomly assigned. Students were free to enroll in any section of the course offered each semester and were not provided any information regarding course design beforehand. Regardless, course demographics were fairly consistent across sections. Table 1 summarizes course demographical information for the sections included in the study. The control group included four sections (fall 2015, spring 2016, fall 2016 & spring 2017) of BSC 110 taught in a traditional style, and the experimental group included four sections of BSC 110 (fall 2017, spring 2018, fall 2018, & fall 2019) following the implementation of a flipped classroom model. Classes meet three times a week for 50 minutes (fall 2018 & fall 2019) or twice a week for 75 minutes (all other sections). Archived course data were collected and analyzed following the exemption of this study by the USM Institutional Review Board (Appendix B).

Table 1

Demographic data by class section

	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Fall 2017	Spring 2018	Fall 2018	Fall 2019
Total # of students	115	114	108	50	112	121	164	106
Average age	20	19	19	20	19	19	18	19
Average ACT	22.1	22.1	23.9	21.9	23.5	23.0	22.8	22.3
White	60%	54%	67%	58%	63%	54%	47%	44%
Black/African American	31%	39%	22%	40%	26%	38%	46%	45%
Other ethnicities (combined)	9%	7%	11%	2%	11%	8%	7%	11%
Female	69%	73%	82%	74%	68%	74%	81%	78%
Male	31%	27%	18%	26%	32%	26%	19%	22%
Pell grant eligible	50%	60%	42%	44%	44%	46%	53%	64%
First-generation students	43%	40%	35%	34%	24%	21%	24%	33%

*Class size was markedly smaller in the spring of 2017 and larger than expected in the fall of 2018.

Pre-Intervention: Traditional Course Design

The traditional course design for BSC 110 utilized a teacher-centered, lecture-intensive approach. Sections of the course were typically high-enrollment (over 100 students) and taught in large theater-style auditoriums. Students were assigned specific pre-class readings from the textbook and online homework via the textbook publisher’s digital supplements. Students were also provided with the lecture PowerPoints before class. Lectures involved the projection of the PowerPoint for a given content area (Appendix C) accompanied by the instructor’s detailed explanation of the content. However, minimal course time (10 minutes or less) was dedicated to discussions or completing activities for deeper understanding. Interactions with the instructor were limited to student questions throughout the lecture and one-on-one interactions outside of class during the instructor's office hours. Opportunities for peer collaborations or small group discussions were brief and infrequent. The only form of peer instruction was also available outside of class through visits to the school's tutorial center. Research indicates active learning class designs may improve student outcomes and increase mastery, but most of the class time was dedicated to lectures and trying to cover all the essential course material.

Post-Intervention Flipped Course Structure

The rationale for implementing a flipped classroom design was to free up some of this valuable class time for active learning practices. Enrollment for the course remained high (over 100 students) but after the spring of 2017, it was taught in a classroom designed for active learning. The curriculum in the traditional course was used to develop the flipped class curriculum (Table 2).

Table 2

Curricular comparison for the traditional and flipped course designs

Concepts Covered*: Pre-class textbook reading & online homework assigned. In-class lecture, minimal group work*	Concepts Covered*: Pre-class textbook reading, online homework, and recorded lectures assigned. In-class minimal lecture, extensive group work*
Atoms, Molecules & Water	Atoms, Molecules & Water
Organic Molecules	Organic Molecules
EXAM 1	EXAM 1
Cells	Cells
Membrane structure and transport	Membrane structure and transport
Cell Signaling	Cell Signaling
EXAM 2	EXAM 2
Energy and enzymes	Energy and enzymes
Photosynthesis	Photosynthesis
Cellular respiration	Cellular respiration
EXAM 3	EXAM 3

Table 2 (continued).

DNA structure and replication	DNA structure and replication
Gene Expression:	Gene Expression:
Transcription/Translation	Transcription/Translation
Genetic Regulation/Mutations	Genetic Regulation/Mutations
EXAM 4	EXAM 4
Cell Division: Mitosis/Meiosis	Cell Division: Mitosis/Meiosis
Patterns of Inheritance	Patterns of Inheritance
FINAL EXAM	FINAL EXAM

Students were provided the same information and the same topics were covered in the textbook, but the lectures were delivered outside of class. Short videos (between 5-10 minutes each) were created by the researcher using Yuja software and were presented as voice-over PowerPoints. Lecture videos were placed on the Canvas LMS, and students were explicitly informed which lectures to view before attending a class meeting. Students were strongly encouraged to use the provided PowerPoint as an outline and to take notes as they viewed the recorded lectures. The first 10-15 min of class time was spent briefly reviewing the lecture material and answering content-specific questions. The remainder of class time was devoted to active learning with students working within self-selected or randomly pre-assigned groups of no more than 4 to complete various forms of activities. Students were instructed to work collaboratively within their group to complete activities while the LAs and the researcher circulated throughout the room to provide guidance where needed. In addition to answering questions, LAs and the researcher continually observed group interactions taking advantage of opportunities to correct misconceptions and to help resolve any disagreements. After a designated time had elapsed, groups were selected at random to share activity answers and to describe how they reached these conclusions as a group. Table 3 provides a comparison of how class time was allocated in the traditional and flipped classes. An outline of the division of work between class and home for the two different course designs is illustrated in Figure 1. Multiple forms of activities were utilized, many being inquiry-driven to facilitate the development of problem-solving and critical thinking skills. When presenting difficult or complex concepts, a sequence of activities at different cognitive levels was completed over multiple class meetings. This type of scaffolding requires that students draw on previous knowledge and experiences to support the construction of new knowledge and emphasize connections between concepts (Appendix D).

Variables

The primary dependent variable for this study is student success as measured by course section exam score means and the percentage of students failing to complete the course with a grade of C or higher. The independent variables for this study are course design (traditional or flipped), ethnicity (white or black or African American) Pell grant eligibility, and first-generation student status.

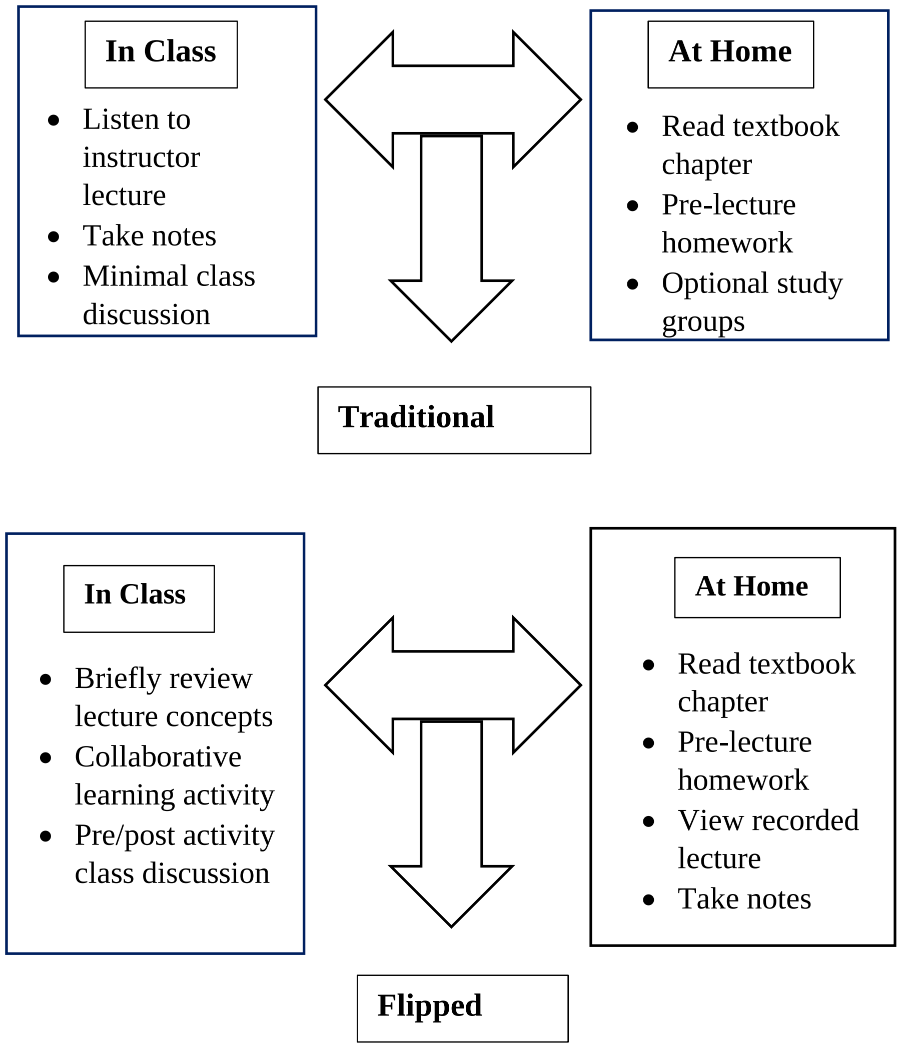
Table 3

Comparison of time allocation in traditional or flipped 50-minute class period

	Traditional Class	**Flipped Class**
Review of previous material	5 - 10 minutes	
Lecture on new content	25 - 30 minutes	5 - 10 minutes
Class-level discussion	5 minutes	15 minutes
Small group collaborations	5 minutes	25 - 30 minutes

Figure 1.

Classroom design before and after the flipped class intervention



Measures

Student success was measured in part using section exam score means. Five non-cumulative exams were given per semester and scores were recorded as percent correct from 0 to 100. Exams were made up of only multiple-choice and matching questions and were given at approximately the same point in the semester covering the same topics at the same level of rigor. The lowest score for the five exams was not included in course grade calculations. Therefore, many students chose not to complete the final exam. Final exam score means were excluded from this study and outcome comparisons were based on course section means for exams one through four. The second measure of student success assessed was the DFW rate. The most prominent ethnicities (white/black or African American), Pell grant eligibility, and first-generation college student status were included as independent variables to determine if the flipped class intervention impacted the DFW rates of one, or more, of these populations differently.

Instrumentation

A customized Student Assessment of Learning Gains (SALG) survey was used as a means of formative assessment and student feedback. The original SALG instrument, developed by Elaine Seymour in 1997, asks students to consider how 18 different instructional elements impact their learning experience (Seymore et al., 1997). The customizable survey has proven a powerful, valid and reliable tool for the formative evaluation of course design and assessment of how students perceive the impact of specific course attributes on their individual learning gains (Seymore et al., 1997; John Gardner Institute 2018; Vishnumolakala et al., 2016). The SALG was administered each fall in all sections of pre-determined gateway courses as part of the guidelines for USM's continued participation in the G2C program. The customized SALG (Appendix E) was disseminated either online or in paper format at the end of the semester. Students were informed that their participation in the survey was voluntary and anonymous. Students were asked multiple questions on a Likert-type scale of 1-5, with 1 indicating no help with learning or understanding, and 5 indicating great help with learning or understanding. The SALG questions were designed to encourage students to reflect on and identify how much different aspects of the course design helped with their learning or understanding of class content. The survey is grouped into seven sections. Questions 1& 2 contain components related to the class overall in relation to learning; Questions 3-5 are related to the impact of specific class activities on learning; Questions 6-9 relate to the influence of assignments, activities, and exams on learning; Questions 10-12 focus on how the information provided to students affected learning; Questions 13-14 are designed to assess how student learning was influenced by peer support; Questions 15 & 16 required students to reflect on how classwork increased understanding of class content; and Question 17 related to how the course affected student attitude about resource utilization.

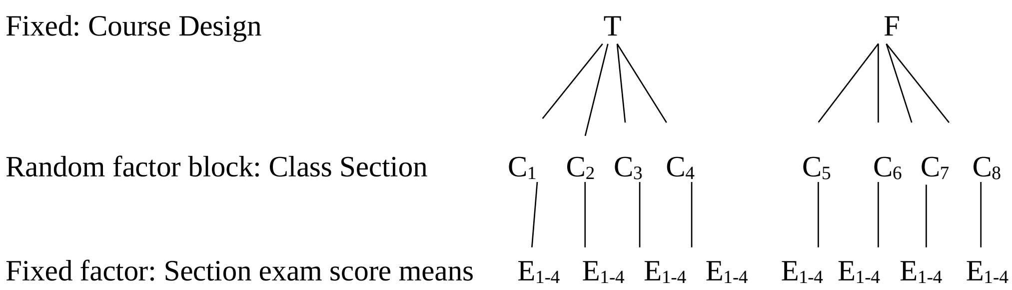
Statistical Analysis

All statistical analyses were performed using SPSS, version 28.0 with a level of significance set at ≤ 0.05. After determining the normal assumptions of a parametric test had been met, an analysis of variance (ANOVA) was conducted to determine the effect of the flipped class intervention on student success as measured by class section mean exam scores. A two-way mixed ANOVA was constructed with course design (traditional or flipped) as a fixed factor, class section as a random effect nested with course design, and section exam score means as the dependent response variable (Figure 2). This model allowed for testing the following specific null hypotheses: 1) Ho: Mean course section exam scores are not significantly statistically different between course designs. 2) Ho: Mean course section exam scores are not significantly statistically different within a class section. 3) Ho: There is no interaction between course design and course section exam score means.

Figure 2.

Two-way mixed ANOVA model

Ho: Mean course section exam scores are not significantly statistically different between course designs.
Ho: Mean course section exam scores are not significantly statistically different within a class section.
Ho: There is no interaction between course design and course section exam score means.



Once normal assumptions of a parametric test had been confirmed, to assess the impact of the flipped class intervention on DFW rates a one-way ANOVA was carried out with total DFW rate by course section as the sole independent variable. This analysis was used to test the following specific null hypothesis: Ho: The effect of course design on the DFW rate is the same between course designs. To determine the potential differential impact on the DFW rate and tackle the third research question, three separate 2-way ANOVA analyses were conducted. Each analysis included class design as a fixed factor and one independent variable (ethnicity, Pell grant eligibility, first-generation status) with DFW rate as the dependent (response) variable. This model utilized binomial data for course design (traditional/flipped), Pell grant eligible (yes/no), first-generation status (yes/no), and ethnicity (black or African American/white) with DFW rate as the continuous response variable. This model allowed the researcher to test the following null hypothesis: Ho: The effect of course design on the DFW rate is the same between course designs when controlling for ethnicity, Pell grant eligibility, or first-generation status.

A mixed-methods approach was used to answer the final research question and analyze data collected from the Student Assessment of Learning Gains survey to assess student perceptions of their learning. Using a two-tailed independent t test, mean responses to SALG Likert scale questions were compared to determine if a significant difference was observed in students' perceived learning gains between the traditional lecture and flipped classes. Even though a two-tailed test is slightly less powerful, the research question does not specify the direction in which student perception of learning gains may change. An independent *t*-test is a commonly used method for statistical evaluation purposes. Its effectiveness has been demonstrated throughout educational research. Although the sample size is small for each question, which might not ensure the required normal distribution the *t*-test statistic was applied to provide an indication of the statistical significance of any changes in student perspectives. Joshi et al (2015) acknowledge some debate regarding the treatment of Likert responses as interval, rather than ordinal data. However, the contention is when responses from multiple individuals are combined for a given question or category of questions, it is appropriate to assign an interval scale for which measures such as mean and analyses like a t test are appropriate (Joshi et al, 2015).

In addition to the quantifiable Likert responses, students were asked to complete a single open-ended question requiring they reflect on how specific class activities contributed to their learning. Insightful and meaningful qualitative research depends on the perspectives of study participants being genuinely and cohesively represented by the researcher. Thematic analysis allows for the emergence of data-driven categories to address specific research questions and the advancement of themes grounded within the theoretical framework of a study (Kiger & Varpio, 2020). The process of analyzing the qualitative data utilizing thematic analysis begins with coding to identify patterns and categories within student responses to create single word or phrase categories. This is similar to the processes of grounded theory and other code-dependent methods (Kiger & Varpio, 2020). The primary goal of coding in thematic analysis is to allow one to recognize logical and persuasive themes that emerge from the data. Braun and Clark (2006) contend "A theme captures something important about the data in relation to the research question and represents some level of patterned response or meaning within the data set (p. 82), and that "the development of the themes themselves involves interpretative work, and the analysis that is produced is not just description, but is already theorized" (p. 84). This type of robust analysis of data is suitable for exploring shared experiences or common meanings across a data set (Braun & Clark, 2006).

The thematic analysis approach can be employed within an inquiry framework that provides interdisciplinary flexibility for analyzing data through the repetitious progression through a series of interconnected stages (Peel, 2020). As reported by Kiger & Varpio (2020), "The most widely-accepted framework for conducting thematic analysis involves a six-step process: familiarizing yourself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report" (p. 2), and that following this method can help ensure data is carefully and fully explored. This approach is distinctive due to the "researcher-active perspective that is used to describe the processes of data collection and analysis" (Peel, 2020, p. 3). To conduct a complete, in-depth analysis of the data, a deductive approach was used to analyze open-ended responses from students enrolled in BSC 110 taught with a traditional or flipped class design. The use of thematic analysis framed by Constructivist Theory allowed data to be gathered and organized into meaningful patterns that provided perspective toward addressing the specific research question of this study related to student perceptions of learning gains (Braun & Clarke, 2006).

CHAPTER IV – RESULTS

The primary goal of the study was to assess the efficacy of a pedagogical intervention involving a flipped classroom design incorporating Learning Assistants at increasing student success in a high enrollment, introductory-level biology course. To determine this, course section exam score means and DFW rates were examined and compared for traditional and flipped class sections. Additionally, surveys were used to examine if the intervention resulted in changes in how students perceived their learning gains. Results are organized into sections based on the research questions.

Research Question One: Is there a statistically significant difference in academic success in the course sections taught with a flipped class design versus the traditional class design sections?

A two-way ANOVA was conducted to investigate the impact of course design (traditional vs. flipped) on mean section exam scores with each course section. Table 4 details descriptive statistics for course section exam scores and the results of the ANOVA analysis are summarized in Table 5. There was a significant effect of course design ($p \leq 0.02$), with the overall exam score mean for flipped course sections (76) being higher than the overall exam mean for traditional course sections (70) (Figure 3). There was substantial variation for exam means (Figure 4) within each course section ($p \leq 1.15$). However, there was a lack of a significant interaction for course design by course section ($p \leq 0.34$) indicating the magnitude of the effect was the same for all exams (Figure 4). While there is evidence for a difference in course exam score means between course designs, the results of this analysis fail to reject the remaining two null hypotheses (no difference in course exam score means between course designs and no interaction between course design and course section exam score means).

Table 4

Exam descriptive statistics for traditional and flipped course sections

		N	Mean	Std. Deviation	Std. Error Mean
Exam 1	Traditional	4	78	3.20	1.60
	Flipped	4	82	2.50	1.25
Exam 2	Traditional	4	75	3.69	1.84
	Flipped	4	83	2.98	1.49
Exam 3	Traditional	4	59	2.94	1.47
	Flipped	4	64	2.21	1.10
Exam 4	Traditional	4	68	3.86	1.93
	Flipped	4	74	4.42	2.21
All Exams	Traditional	4	70	3.16	1.58
	Flipped	4	76	1.70	.853

Table 5

Results of two-way ANOVA analysis of course section exam score means

	Sum of Squares	*df*	Mean Square	F statistic	P value
Between					
Course design	253.1	1	253.1	9.08	.024
Residuals	167.2	6	27.88		
Within					
Exam means	1681.6	3	560.5	107.5	1.15
Course design * Exam means	118.6	3	1.19	1.19	.343
Residuals	94.2	18	5.2		

Figure 3.

Mean exam score by course design

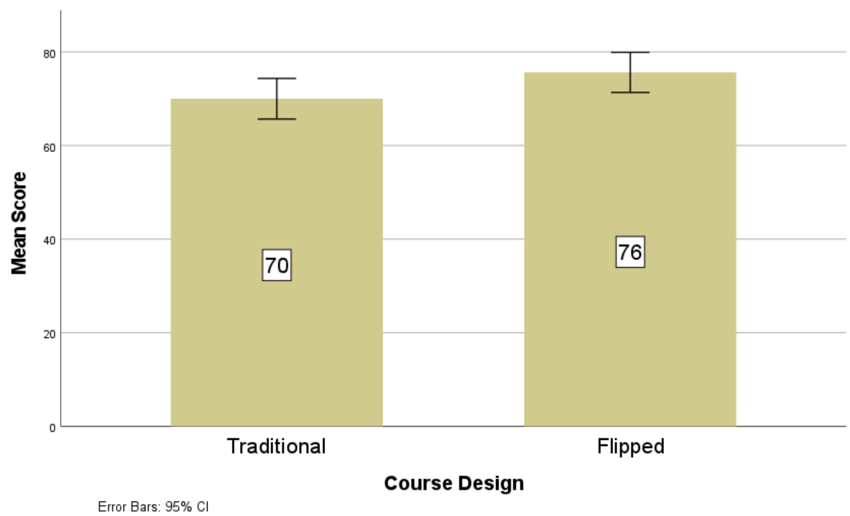
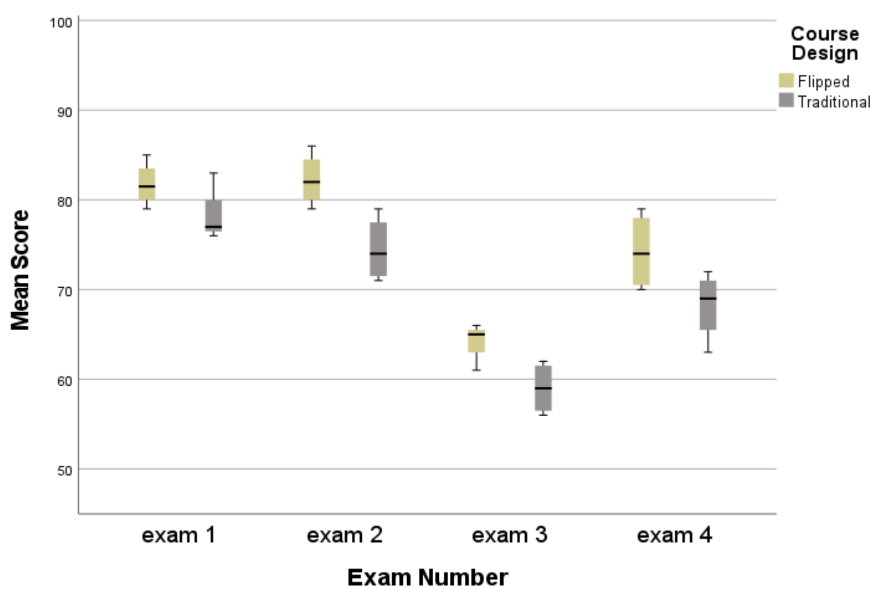


Figure 4.

Mean exam scores by treatment



Error Bars: 95% CI

Research Question Two: Is there a statistically significant difference in the DFW rates in the flipped class sections versus the traditional class sections?

A one-way ANOVA was carried out with the total DFW rate by course section with the independent variable of course design (Figure 5a). This analysis was used to test the following specific null hypothesis: Ho: The effect of course design on the DFW rate is the same between course designs. The mean DFW rate was lower for flipped design sections (.243, SD .074) than for traditional design sections (.335, SD .084), but the ANOVA analysis (Table 6) revealed the difference was not statistically significant ($p \leq 0.149$). Therefore, the analysis failed to reject the null hypothesis as there is insufficient evidence to conclude that DFW rates are statistically significantly different between the course designs.

Table 6

One-way ANOVA analysis of DFW rates by the course design

	Sum of Squares	*df*	Mean Square	F statistic	p value
Course design	.017	1	.02	2.75	.149
Residuals	.037	6	.01		

Research Question Three: Is there a statistically significant difference, when controlling for ethnicity, Pell grant status, and first-generation status, in the DFW rates in the flipped class sections versus the traditional class sections?

The DFW rate, reported as a percentage, by course section for each category used in the analysis is summarized in Table 7. Three separate 2-way ANOVA analyses were conducted to determine the potential differential impact on the DFW rate (Figure 5 b-d). Each two-way ANOVA analysis included class design as a fixed factor and one independent variable to test the following Ho: The effect of course design on the DFW rate is the same between course designs when controlling for ethnicity, Pell grant eligibility, or first-generation status.

Table 7

Categorized DFW rate percentages by course section

	Fall 2015	Spring 2016	Fall 2016	Spring 2017	Total Traditional	Fall 2017	Spring 2018	Fall 2018	Fall 2019	Total Flipped
Black or African American	18.3	21.9	7.41	14.0	15.4	8.0	14.9	18.3	20.6	15.5
White	13.9	18.4	13.0	22.0	16.8	6.2	2.5	7.3	7.6	5.9
Pell grant eligible	19.1	17.5	6.9	14.0	14.3	6.3	4.1	7.9	10.4	7.2
Not Pell grant eligible	14.8	24.6	15.7	22.0	19.3	9.8	16.5	18.9	22.6	17.0
First-generation	24.4	28.1	9.3	12.0	18.4	10.7	17.4	19.5	24.5	18.0
Not first-generation	9.6	14.0	13.0	24.0	15.1	5.4	3.3	7.3	8.5	6.1
Total rate by section	33.9	42.1	22.2	36.0	33.6	16.1	20.7	26.8	33.0	24.2

Table 8

Two-way ANOVA analysis of DFW rates controlling for ethnicity, Pell grant eligibility, and first-generation status

	Sum of Squares	*df*	Mean Square	F statistic	p value
Pell grant eligibility					
Course design	.01	1	.01	2.11	.172
Pell grant	.02	1	.02	5.74	.034
Course design * Pell grant	.01	1	.01	2.11	.172
Residuals	.05	12	.00		

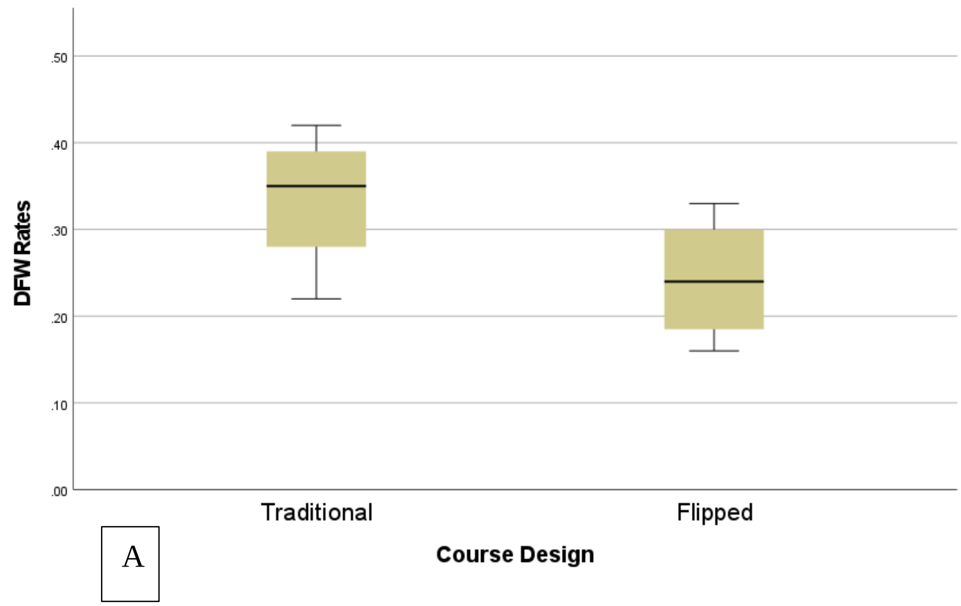
Table 8 (continued).

First-generation status					
Course design	.01	1	.01	4.28	.061
First-generation	.02	1	.02	10.46	.007
Course design * First-generation	.00	1	.00	1.24	.287
Residuals	.03	12	.00		
Ethnicity					
Course design	.01	1	.01	4.68	.051
Ethnicity	.01	1	.01	2.63	.131
Course design * Ethnicity	.01	1	.01	6.19	.029
Residuals	.03	12	.00		

Results of the DFW analysis (Table 8) indicate Pell grant eligibility has a statistically significant effect on DFW rate ($p \leq 0.034$). However, there was no significant difference in DFW rate across course design ($p \leq 0.172$), nor was any interaction between main effects observed ($p \leq 0.172$). This leads to rejecting the null hypothesis that DFW rates are the same regardless of Pell grant eligibility, but a failure to reject the null hypothesis that DFW rate is the same across course design regardless of Pell grant status. The analysis of first-generation status yielded similar results with first-generation status proving to have a significant effect ($p \leq 0.007$) on DFW rate with no significant difference across course design ($p \leq 0.172$), and no significant interaction effect ($p \leq 0.287$). However, for ethnicity, there was no significant effect of ethnicity ($p \leq 0.131$) on the DFW rate, but there was a significant effect of course design ($p \leq 0.051$), and a significant interaction between main effects ($p \leq 0.029$). Therefore, while the DFW rate was not different between ethnic groups, the interaction of Course design*Ethnicity indicates a significant relationship between ethnicity and DFW rate depending on course design (Figure 5).

Figure 5.

Variation in DFW rate by course design for A) all sections of each design, B) by Pell grant eligibility, C) by first-generation status, and D) by ethnicity



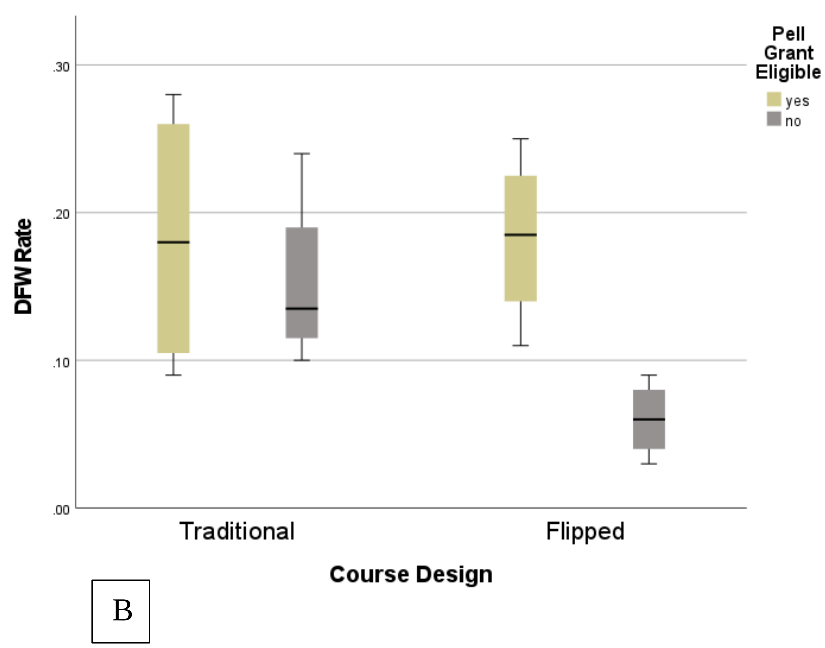
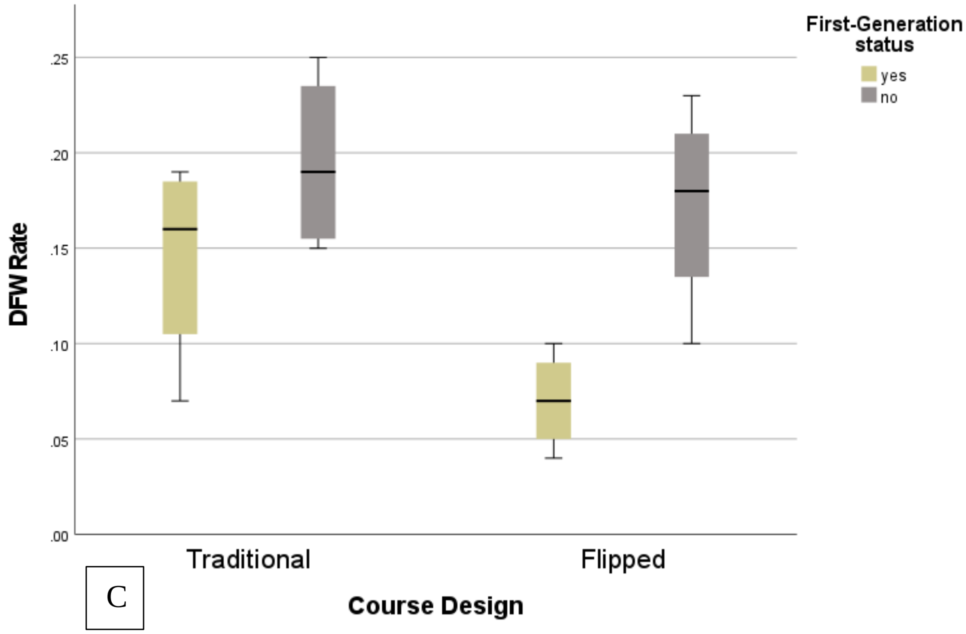
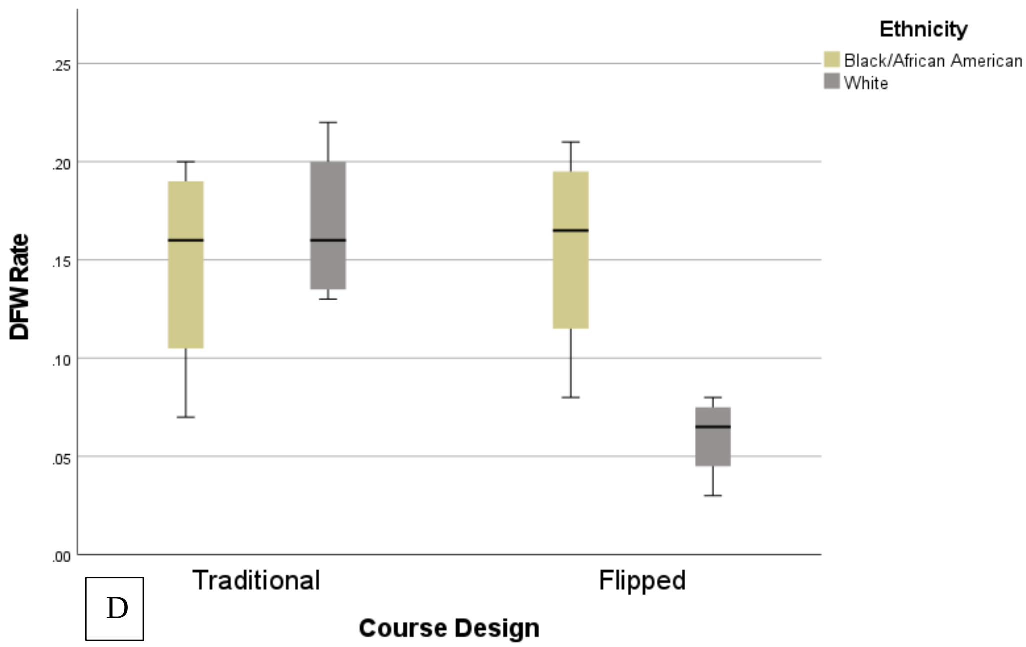


Figure 5 (continued).





Error Bars: 95% CI

Research Question Four: How has the redesign to a flipped classroom model with the addition of active learning facilitated by peer Learning Assistants influenced how students assessed their own learning, as measured by the Student Assessment of Learning Gains (SALG) survey?

Student Assessment of Learning Gains Survey Statistical Analysis

Students enrolled in all sections of BSC 110 completed the SALG at the end of each fall semester (beginning fall 2015) to provide their views on the influence of specific course characteristics on learning gains and level of understanding. The survey contained 18 Likert-type questions (scale of 1-5, 1 indicating no help with learning or understanding, and 5 indicating great help) divided into multiple thematic sections and one open-ended question. The percentage of surveys distributed, and the percent completed (including open-ended responses) for each section under study are outlined in Table 9. Descriptive statistics (mean and standard deviation) were calculated for each question for each class section (Table 10).

Table 9

Percentage of SALG respondents in each section

		Surveys Distributed	Surveys Completed		Open-ended Response	
Course Section	Course Design	N	N	%	N	%
Fall 2015	Traditional	115	97	84.3	34	29.6
Fall 2016	Traditional	108	73	67.6	32	29.6
Fall 2017	Flipped	112	64	57.1	39	34.8
Fall 2018	Flipped	164	139	84.8	88	53.7
Fall 2019	Flipped	106	82	77.4	38	35.8

Table 10

Mean SALG responses by the course design

How much did each of the following aspects of the class help your LEARNING?	Fall 2015 n= 97 Mean	SD	Fall 2016 n= 73 Mean	SD	Fall 2017 n= 64 Mean	SD	Fall 2018 n= 139 Mean	SD	Fall 2019 n= 82 Mean	SD
The Class Overall										
How the class topics, activities, reading, and assignments fit together	3.9	1.09	4.0	0.96	4.3	0.85	4.1	0.92	4.15	0.90
The pace of the class	3.4	1.18	3.4	1.20	3.8	0.99	3.7	1.08	3.65	1.18
Class Activities										
Participating in discussions during class	3.1	1.18	3.3	1.22	3.5	1.20	3.8	1.07	3.91	1.11
Participating in group work during class	2.6	1.31	3.1	1.24	4.0	1.10	4.4	0.86	4.32	0.95
Doing hands-on class activities	2.9	1.48	3.4	1.32	4.3	0.92	4.4	0.84	4.40	0.87
Assignments, graded activities, and tests										
Graded assignments (overall) in this class	3.6	1.09	3.8	1.11	4.1	0.86	3.8	0.91	3.86	1.19
The number and spacing of tests	3.8	1.22	3.9	1.16	4.0	1.18	4.0	0.98	3.65	1.22
The way the grading system helped me understand what I needed to work on	3.4	1.27	3.7	1.24	3.8	1.14	3.4	1.25	3.84	1.35
The feedback on my work received after tests or assignments	3.2	1.34	3.5	1.27	3.3	1.25	3.4	1.22	3.53	1.46
The information you were given										
Explanation of how the class activities, reading and assignments related to each other	3.7	1.10	3.7	1.20	4.2	0.91	4.0	0.97	4.01	1.14
Explanation given by instructor of how to learn or study the materials	3.8	1.18	3.8	1.17	4.1	1.00	3.8	1.12	3.78	1.24
Explanation of why the class focused on the topics presented	3.7	1.18	3.8	1.15	4.0	1.08	3.8	1.13	3.82	1.17

Table 10 (continued).

Support for you as an individual learner										
Working with peers during class	3.1	1.27	3.3	1.31	4.2	1.00	4.5	0.88	4.34	1.01
Working with peers outside of class	3.4	1.18	3.8	1.24	3.6	1.36	4.0	1.09	3.79	1.42
As a result of your work in this class, what gains did you make in your UNDERSTANDING of each of the following?										
Your understanding of class content										
The main concepts explored in this class	3.8	1.10	3.8	1.03	4.1	0.94	4.0	0.92	4.13	0.89
The relationships between the main Concepts	3.8	1.16	3.8	1.02	4.0	1.01	3.9	0.96	4.10	0.92
As a result of your work in this class, what GAINS did you make in the following?										
Class impact on your attitudes										
Willingness to seek help from others (teacher, peers, TA) when working on academic problems	3.4	1.36	3.8	1.08	3.9	1.01	3.8	1.15	4.01	1.12

Note: Course sections in falls 2015 and 2016 were taught with a traditional course design, and sections in falls 2017, 2018, and 2019 were taught using the flipped class model.

A two-tailed independent t test was used to examine response means for SALG Likert scale questions to determine if a significant difference was observed in students' perceived learning gains between the traditional lecture and flipped classes (Table 11).

Table 11

Two-tailed t test for SALG responses by course design

How much did each of the following aspects of the class help your LEARNING?	Traditional n= 170 Mean	SD	Flipped n= 283 Mean	SD	t statistic	*df*	p value
The Class Overall							
How the class topics, activities, reading, and assignments fit together	3.9	.071	4.2	.104	2.71	3	.073
The pace of the class	3.4	.000	3.7	.076	5.56	3	.011
Class Activities							
Participating in discussions during class	3.2	.141	3.7	.212	3.07	3	.055
Participating in group work during class	2.9	.353	4.2	.211	5.69	3	.011
Doing hands-on class activities	3.2	.353	4.4	.057	6.36	3	.008
Assignments, graded activities, and tests							
Graded assignments (overall) in this class	3.7	.141	3.9	.158	1.57	3	.214
The number and spacing of tests	3.8	.070	3.9	.202	0.22	3	.844
The way the grading system helped me understand what I needed to work on	3.6	.212	3.7	.243	0.61	3	.585
The feedback on my work received after tests or assignments	3.4	.212	3.4	.115	0.43	3	.699
The information you were given							
Explanation of how the class activities, reading and assignments related to each other	3.7	.000	4.0	.112	4.41	3	.022
Explanation given by instructor of how to learn or study the materials	3.8	.000	3.9	.179	0.69	3	.535
Explanation of why the class focused on the topics presented	3.8	.070	3.9	.110	1.37	3	.265
Support for you as an individual learner							
Working with peers during class	3.2	.141	4.3	.150	8.53	3	.003
Working with peers outside of class	3.6	.282	3.8	.200	0.93	3	.420
As a result of your work in this class, what gains did you make in your UNDERSTANDING of each of the following?							
Your understanding of class content							
The main concepts explored in this class	3.8	.000	4.1	.068	5.46	3	.012
The relationships between the main concepts	3.8	.000	4.0	.100	2.68	3	.075

Table 11 (continued).

As a result of your work in this class, what GAINS did you make in the following?							
Class impact on your attitudes							
Willingness to seek help from others (teacher, peers, TA) when working on academic problems	3.6	.282	3.9	.105	1.801	3	.169

Only six of the seventeen questions on the SALG had mean responses that were statistically significantly different between course designs. However, response means increased for all but one question after the flipped class intervention. Between course designs, the "Participating in group work during class" item improved from 2.9 to 4.2 ($p \leq 0.011$) while the item "Doing hands-on class activities" improved from 3.2 to 4.3 ($p \leq 0.008$) and "Working with peers during class" improved from 3.2 to 4.3 ($p \leq 0.003$). The other three statistically significant responses were related to the pace of the class (from 3.4 – 3.7, $p \leq 0.011$), explanation of how course activities were related (from 3.7 – 4.0, $p \leq 0.022$), and understanding of main course concepts (from 3.8 – 4.1, $p \leq 0.012$).

Student Assessment of Learning Gains Survey Thematic Analysis

A thematic analysis was employed to analyze responses to the following SALG open-ended question: "Please comment on how the class activities (discussions, group work, and/ or hands-on class activities) helped your learning (Appendix F). The six-stage guide detailed by Braun and Clarke (2006) was used to guide the process of thematic analysis. Stage one: "Familiarizing yourself with your data" which "involves 'repeated reading' of the data and reading the data in an active way …. searching for meanings, patterns" (Braun & Clarke, 2006, p. 87). To ensure student responses were thoroughly explored, the researcher read each set of responses four times while making and revising notes for any common language or patterns observed. Stage two: "Generating initial codes" allows one to "identify a feature of the data (semantic content or latent) that appears interesting to the analyst" (Braun & Clarke, 2006, p. 88). The data were collapsed into codes to organize the information into meaningful categories. The following 12 codes were gleaned from the data: 1) group work as a negative, 2) group work as a positive, 3) others' perspective beneficial, 4) deeper understanding, 5) lecture outside of class as a positive, 6) application of content, 7) class discussions as a positive, 8) no activities or group work, 9) activities helpful, 10) increased interest or attention, 11) helpfulness of LAs, and 12) increased clarity or decreased fear. Table 12 includes sample data extracts with codes applied.

Table 12

Data extracts from SALG responses with codes applied

Data Excerpt	**Coded For**
Bouncing ideas off of each other and having to voice the thought process is helpful (fall 18)	Group work as a positive
We never had much group work unless you decided to outside of class (fall 15)	No activities or group work
It allowed me to listen to how other people thought on numerous points; gave me alternate ways to understand material (fall 16)	Others' perspectives beneficial
I enjoyed group work because I was able to learn from classmates and have them learn from me. The discussions helped me on information that was not clear. The group work also helped me learn new things from my fellow classmates about the lesson and I also was able to share my knowledge to help them. (fall 16)	1) Others' perspectives beneficial 2) Class discussions as a positive 3) Others' perspectives beneficial
Hands on is the best for me, it helps it go from information to something I understand (fall 15)	Deeper understanding

Table 12 (continued).

It is more interesting to do hands on than it is to just sit and listen. (fall 18)	Increased interest or attention
It was very helpful to do hands-on because it is a different form of learning that makes you apply things that you just have learned. (fall 17)	Application of content
Greatly helped in understanding the material, and showed how to use the knowledge (fall 17)	1) Deeper understanding 2) Application of content
I loved that there were multiple resources (textbook, online assignments, extra credit, group activities, and ESPECIALLY the recorded lectures) to help us succeed. (fall 18)	Lecture outside of class as a positive
They helped because I would understand from my peers, as well as the LAs. (fall 17)	1) Group work as a positive 2) Helpfulness of LAs
The class activities helped my learning by being able to work in groups. Oftentimes, it's difficult to ask questions out loud to the professor, but by being in a small group it is easier to ask those questions. The LA's were also a great help, in answering any questions that my group (and others) had. (fall 17)	1) Group work as a positive 2) Increased clarity or decreased fear 3) Helpfulness of LAs
Discussions cleared up misunderstood info. Group work did not help. Hands-on activities helped me a lot. (fall 18)	1) Class discussions as a positive 2) Group work as a negative 3) Activities helpful

Stage three: “Searching for themes” which “re-focuses the analysis at the broader level of themes, rather than codes, involves sorting the different codes into potential themes”. (Braun & Clarke, 2006, p. 89). Codes developed in the previous phase were examined and sorted to identify emergent themes and sub-themes. The initial themes and sub-themes were 1) group work (1a. beneficial, 1b. negative perception), 1c. no group work), 2) collaboration (2a. benefit of other’s perspectives) 3) benefit of discussion, 4) deeper understanding, 5) activities (5a. increased learning, 5b. application of content). Percentage of responders independently expressing these ideas is portrayed in Table 13.

Table 13

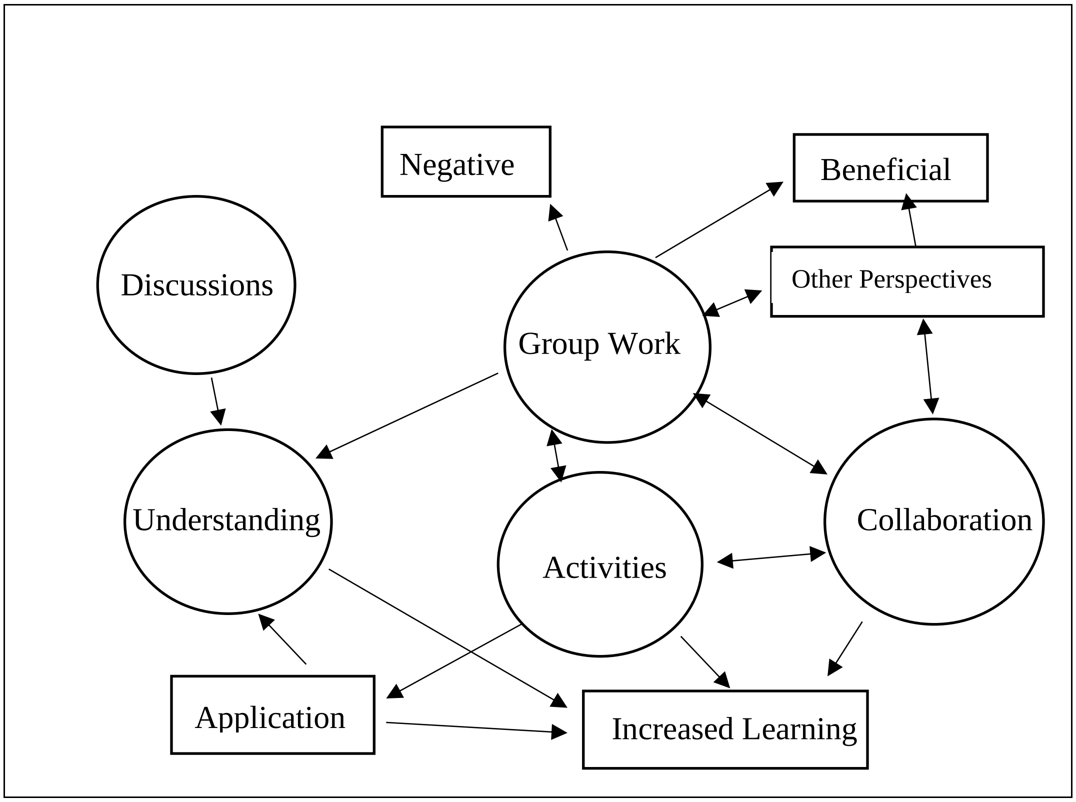
Initial themes and sub-themes identified from SALG responses and the percentage of individuals who expressed these ideas

	% of Individuals		
	Traditional	Flipped	Total
Themes and *Sub-themes*	n=66	n=165	N=231
Group work			
Beneficial	12	24	21
Negative perception	0	3	1
Minimal to no groupwork	24	0	10
Collaboration			
Benefit of others' perspectives	20	12	14
Benefit of discussion	21	3	10
Deeper understanding	11	25	16
Activities			
Increased learning	3	12	6
Application of content	0	8	5

Stage four: "Reviewing themes" which requires "checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis" (Braun & Clarke, 2006, p. 87). A two-level analysis was employed to determine if there was a logical pattern for codes within each theme and for the themes within the data set as a whole. Figure 6 illustrates the initial thematic map presenting 5 major themes. Stage five: "Defining and naming themes", wherein the research must "define and further refine the themes you will present for your analysis, and analyze the data within them", with the goal of "clearly define what your themes are and what they are not" (Braun & Clarke, 2006, p. 92).

Figure 6.

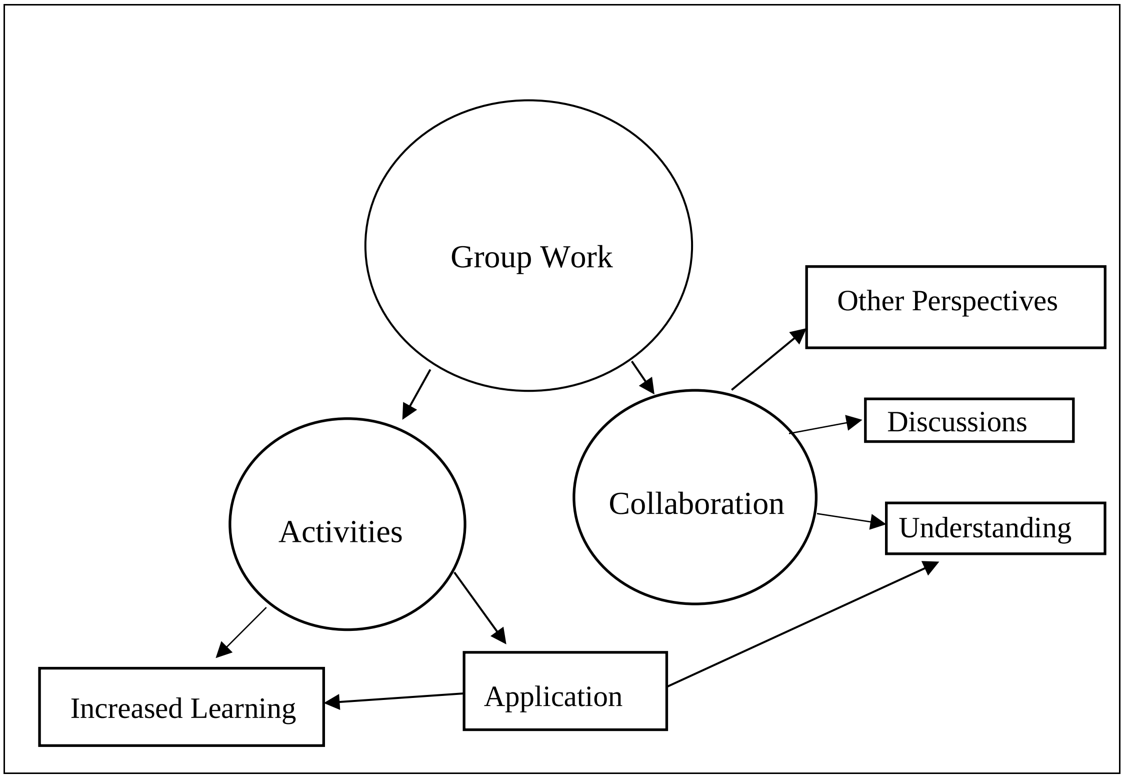
Initial thematic map, showing five main themes



The final thematic map (Figure 7) was narrowed down to represent the one major theme of group work and two sub-themes of collaboration and activities. Stage six: "Producing the report" directs the research to "tell the complicated story of your data in a way which convinces the reader of the merit and validity of your analysis" (Braun & Clarke, 2006, p. 93). A thematic analysis narrative is included within the next chapter to provide a discussion of the story revealed by the data analysis both within the main themes and across sub-themes.

Figure 7.

Final thematic map, displaying one main theme and two sub-themes



CHAPTER V - CONCLUSIONS & DISCUSSION

An educator's research into their teaching presents the opportunity for direct improvement of practice and the potential to initiate conversations for institutional-level change. Classroom action research is based on data rather than relying on reflective behaviors alone (Beer, 2019). The steps of this type of research follow a pathway of identifying a problem, planning an intervention, analyzing data, then evaluating the impact of the intervention (Laudonia et al., 2018). Findings of this type of research can be used to inform curricular decisions to better meet the needs of students and foster academic success. Per Beer (2019), "educational research trickles down very slowly before it finally affects teaching practices" (p. 480). This form of applied research can be used to address a specific problem or investigate the impact of a specific intervention, such as the incorporation of a cooperative learning activity. It also provides the flexibility to focus on student learning or teacher efficacy as the subject when investigating tools like pedagogies or learning strategies (Beer, 2019). However, applied research can be employed on a larger scale to investigate best practices for teaching and learning. Through the implementation of qualitative and quantitative data collection and analysis, education research can provide the empirical evidence that is often missing. Within education, active research is often limited to case study approaches, which is useful but might be more generalizable if a theory grounded applied research method was utilized (Laudonia et al., 2018).

The current study adds to the existing body of knowledge by exploring the efficacy of a specific active learning pedagogical intervention on academic success in a large enrollment, introductory-level course. Learner-centered class designs have been supported in the literature as being effective at increasing academic performance and persistence (Abeysekera & Dawson 2015; Bishop & Verleger 2013; Butt 2014; Freeman, et al, 2024; Freeman, Haak & Wenderoth, 2011; Reyneke & Fletcher, 2014). Additionally, research indicates this type of learning environment fosters the development of critical thinking skills and requires higher-order cognitive skills (Haak et al, 2011). There is less empirical data available to support the positive influence of a flipped class design specifically on academic outcomes (Brame, 2013), and it can be challenging to implement in large-enrollment courses especially when students have disparate levels of preparedness. However, it has been proposed that this type of learning environment may level the field and work to reduce these gaps through repetitive opportunities for practice applying content knowledge (Haak et al., 2011). Research suggests the utilization of a Learning Assistant model which provides peer-to-peer instruction, presents a potential solution to this problem (Otero et al., 2006).

Research Question One

The first research question asked if a statistically significant difference in academic success exists in the course sections taught with a flipped class design versus the traditional class design sections. Based on data collected, there was a statistically significant effect of course design ($p \leq 0.02$) on exam scores. A six-point increase in combined exam score means was observed for flipped course sections (76) when compared to traditional course sections (70). This outcome is supported by reports in the literature that cognitive load can be lowered and learning positively affected through the effective use of a flipped classroom model (Bergmann & Sams, 2012; O’Flaherty & Phillips, 2015; Turan & Goktas, 2016). There was a great level of variation between exams, but this can likely be explained by the varying complexity of content covered on each exam. However, data indicate the increase in performance (exam score mean) in the flipped class sections was independent of the exam, which is to say the magnitude of the effect was equal across all four exams.

The flipped class design presented an opportunity to spend face-to-face class time guiding students through the learning process to ensure a deeper understanding of course content. Based on the use of active, cooperative learning within the flipped class sections, the study findings fit with Vygotsky's Zone of Proximal Development suggesting learning gains of individuals are greater through peer interactions than when learners work independently (Erbil, 2020). These peer-to-peer interactions represent scaffolding, which when appropriately implemented may increase learning gains in student populations with highly diverse preparedness toward learning processes, such as metacognitive behavior (Sabel, 2020). One of the general education outcomes measured for BSC 110 is a target of 70% of students scoring 70% or higher on an exam covering basic biological concepts. This outcome (cumulative measure for all sections of BSC 110, not just those taught by the researcher) improved with the target being met for the first time in the academic years 2016-17 & 2017-18. Relocating lectures (extrinsic cognitive load) outside of class through a flipped classroom design should allow students time to process this information in class reducing the intrinsic cognitive load and improving student learning outcomes (Turan & Goktas, 2016; Abeysekera & Dawson, 2014). There was a decline in next year following changes to the semester schedule (class times and semester length) overlapping with a period of increased enrollment.

Research Questions Two and Three

The second research question was to explore whether a statistically significant difference in the DFW rates in the flipped class sections versus the traditional class sections would be observed. In an internal (USM) Quality Enhancement Plan impact report, an analysis of data collected as part of the Gateways to Completion (G2C) program showed an overall reduction in DFW rates across gateway courses between 3-14% between 2016 and 2019. Data analyzed for this study did show the DFW rate to be lower for flipped compared to traditional class sections, but it was not a statistically significant decline ($p \leq 0.149$). The first two semesters after the flipped class intervention saw an overall decline in DFW rates. However, in the fall of 2018 USM changed the semester schedule to lengthen class times and reduce the weeks of the semester. This, coupled with a sharp increase in enrollment in the course, could provide some explanation for the lack of a statistically significant reduction in the DFW rate.

The third research question also looked for a statistically significant difference in the DFW rates in the flipped class sections versus the traditional class sections when controlling for ethnicity, Pell grant status, and first-generation status. Analyses of data related to DFW rates for specific student populations provided mixed results. Pell grant eligibility and first-generation status both had a statistically significant effect on the DFW rate ($p \leq 0.034$ and $p \leq 0.007$, respectively), but there was no significant difference in the DFW rate for either category in relation to course design. A closer examination of data revealed DFW rates were lower, independent of course design, for those not eligible for Pell grants and for individuals declaring first-generation status.

The lower DFW rate for those individuals not eligible for the Pell grant was not unexpected as eligibility for financial-dependent aid is often regarded as a measure of low socioeconomic status. This may lead to college readiness disparities which are particularly evident within large-enrollment STEM courses. There is evidence to suggest a substantial increase in income-related achievement gaps in recent years due in part to greater residential income segregation affecting school-quality differentials and resource allocation (Reardon, 2011). The literature suggests issues with the validity of using Pell grant eligibility as the single measure with which to define this marginalized population. Lucus et al. (2021) did not find Pell grant eligibility to be a suitable predictor of DFW rate in an introductory chemistry course but caution that Pell grant eligibility may not be adequate to make assumptions related to socioeconomic circumstances. They report that 29% of individuals in the lowest socioeconomic percentiles did not have the ability or opportunity to complete the applications necessary for receiving this need-based aid (Lucus et al., 2021). Therefore, the data analysis for this category may not be a reliable and accurate measure of how this intervention specifically impacts this student population.

First-generation students, typically from lower-income families, have many risk factors impeding their ability to succeed academically (four times more likely to leave college after year one), but they are one of the largest groups targeted for systems of support such as Federal TRIO Programs (Engle & Tinto, 2008). At USM, there are various initiatives within the Center for Student Success, however, there are programs like Eagles First that specifically target first-generation students and others, like Academic Coaching for which first-generation and underrepresented minority students are given priority access. While it is true many student support resources are available on campus, it is possible other students are not as aware due to less-ambitious participation campaigns.

With regard to ethnicity, there was no statistically significant difference in the DFW rate between ethnic groups but there was a significant effect of course design on the DFW rate. Inspection of the significant interaction between the main effects revealed white students benefited more (had the lowest DFW rate) from the flipped class intervention. This contradicts previous findings where African Americans were shown to have DFW rates up to twice that of whites and flipped classroom interventions resulted in greater decreases in DFW rates for African Americans and Indigenous peoples compared to whites (Benford & Gess-Newsome, 2006; Van Dusen & Nissien, 2020). In fact, the decrease in the performance gap between continually marginalized students and what is thought of as their dominant peers has not only been reported in individual STEM courses but has proven to be transferable to future courses (Alzen, Langdon, & Otero, 2018). Conversely, Webb, Stade and Grover (2014) reported a significant decrease in DFW rates in a calculus course after implementing an LA program, but the decrease was consistent across ethnic groups.

The implementation of an LA program has been reported to promote a culture of inclusion where those previously feeling ostracized or excluded are encouraged to contribute to the learning process and share experiences (Van Dusen, White, & Roualdes, 2016). Students report viewing LAs as less intimidating than an instructor and are more likely to communicate thoughts and experiences with them (Alzen, Langdon, & Otero, 2018). Three LAs were used within each class section and an effort was made to recruit

LAs mirroring the expected diversity of the course. However, two of the three LAs in three of the four semesters assessed were white (fall 2017, spring 2018 & fall 2018 – two white males & one Indian female; fall 2019 – one white female, one Black female, & one Indian female). Students formed groups through self-selection, and groups tended to be dominated by a single ethnicity. The lack of diversity in some of the LAs recruited may have influenced the willingness of some groups to utilize the LAs as a resource.

There was substantial variation in engagement observed both between and within groups. This included the level at which individuals cooperated with a group to complete tasks and the willingness to ask LAs or the instructor for assistance. It is possible that imposter syndrome played a role in the disparate decline in DFW rates between ethnic groups. According to Le (2019), people identifying as Black or African American are far more impacted in an academic setting by feelings of self-doubt, fear of failure or harsh judgment, and anxiety compared to non-people of color. This lack of confidence in performance potential extended beyond reducing interactions with instructors but also included peer groups (Le, 2019)

Research Question Four

The final research question examined the influence of the flipped class intervention on how students assessed their own learning by analyzing both the Likert scale and open-ended responses to the Student Assessment of Learning Gains (SALG) survey. The SALG was disseminated to each section of BSC at the end of the semester beginning in the fall of 2015. Of the seventeen Likert scale questions on the survey, only six had statistically significantly increased means after the flipped class intervention. Though not significant, response means for ten out of the eleven other questions also increased after the intervention. The mean score for the question regarding the influence of feedback received after tests and assignments on learning remained the same between the course designs. In the methodologies section, it was noted that small sample sizes and the selection of a two-tailed test might reduce the sensitivity and power of the analysis. Regardless, based on the research question which did not specify the direction of the change in mean score, the two-tailed test was the appropriate choice.

The largest changes in response means were observed for the following items: “Participating in group work during class” (2.9 to 4.2, $p \leq 0.011$), “Doing hands-on class activities” (3.2 to 4.3, $p \leq 0.008$), and “Working with peers during class” (3.2 to 4.3, $p \leq 0.003$). This can likely be attributed to the fact that these types of collaborative activities increased dramatically after the implementation of a flipped class design. Revisiting the works of Vygotsky (1962), it is claimed that through cooperative learning, social interactions, and interactions with a mentor or peer, students can accomplish more than they are able to as individuals.

The other three statistically significant responses were related to the pace of the class ($p \leq 0.011$), explanation of how course activities were related ($p \leq 0.022$) and understanding of main course concepts ($p \leq 0.012$). Per Braxton, Milem, and Sullivan (2000), there is a direct correlation between the learning gains of students who participate in active learning and the confidence they feel toward their understanding of course material content. Learners may require time to delve into and explore concepts so presenting course content before class allows students time to consider, research, reflect, and make necessary connections so time spent in class can be reserved for practice and skill development (Bransford, Brown, & Cocking, 2000; Bishop & Vergler, 2013).

Thematic Analysis Narrative

The use of thematic analysis framed by Constructivist Theory allowed data to be gathered and organized into meaningful patterns that provided perspective toward addressing the specific research question of this study related to student perceptions of learning gains (Braun & Clarke, 2006). This was performed using a somewhat inductive approach data coding and theme development were organic with no pre-formed codebook, but the process was based on an existing research question and theoretical construct (Braun & Clarke, 2006). The codes used to organize the data were 1) group work as a negative, 2) group work as a positive, 3) others' perspective beneficial, 4) deeper understanding, 5) lecture outside of class as a positive, 6) application of content, 7) class discussions as a positive, 8) no activities or group work, 9) activities helpful, 10) increased interest or attention, 11) helpfulness of LAs, and 12) increased clarity or decreased fear.

Recorded lectures viewed outside of class allow students to pause and review points of confusion and to take notes at their own pace allowing for better comprehension of course material. According to Caviglia-Harris (2016), students ranked online lecture videos as the most useful aspect of a flipped class, and Kurt (2017) reports self-pacing as a strong contributor to improvements in student achievement. However, only a couple of SALG responses referenced the benefit of recorded lectures outside class. There were also a couple of negative comments about not being taught material before class or the overwhelming volume of outside class work required to prepare.

> "Being able to view the lectures online before class helped me to actually know the information that was being lectured. By knowing the

information before class, I was able to assure my knowledge on the topic." (fall 17_1)

"The recorded lecture offer a lot of help" (fall 18_1)

"They didn't because I wasn't taught the information before being asked to do the activity" (fall 17_2)

"The stuff we had to study outside of class was overwhelming." (fall 18_2)

It appears there was an overall perceived benefit of self-pacing but perhaps some of the information was not comprehended due to a lack of immediate feedback from the instructor while viewing the lectures. It should be noted that the mean response to the Likert scale question related to class pacing increased significantly after their introduction.

The initial themes and sub-themes derived from the codes were 1) group work (1a. beneficial, 1b. negative perception), 1c. no group work), 2) collaboration (2a. benefit of other's perspectives) 3) benefit of discussion, 4) deeper understanding, 5) activities (5a. increased learning, 5b. application of content). This was narrowed down to include one final major theme (group work) and two sub-themes (collaboration and activities). The percentage of individuals mentioning the positive benefit of group work doubled between surveys collected for traditional class sections (12%) and after the implementation of the flipped class design (24%). This illustrates the fact that students are aware of the benefits of group work and that the more frequently they are exposed to this type of learning community the greater the number of individuals acknowledging the benefits to their learning. Within the SALG responses, regardless of class design, there were repeated referrals to the benefit of cooperative learning and gaining insight from the perspective of others, but surprisingly, there were only three (all positive) specific references to the influence of LAs for surveys completed after the implementation of the intervention. Interestingly, more students in the traditional class format (20%) mentioned the benefits of collaboration specifically compared to flipped classes (12%).

> "learning in small groups works better for me) (fall 15_1)
>
> "The group work helps me tremendously (fall17_3)
>
> "Other students were able to help me understand the material from their perspective" (fall 15_2)
>
> "they allowed me to listen to how other people thought on numerous points; gave me alternate ways to understand material" (fall 16_1)
>
> "activities allowed for me to engage in the content with peers and it helped me understand the content having multiple minds thinking about the work." (fall 17_4)
>
> "With the group I was with I gained more understanding during activities since each of us brought strengths and helped each other understand/learn" (fall 18_3)
>
> "LA's were also a great help, in answering any questions that my group (and others) had." (fall 17_5)

After the intervention, there were multiple references to activities allowing for the application of course material resulting in increased learning and an increase in mention of increased learning (3% to 12%) and deeper understanding (11% to 21%).

> "It was very helpful to do hands-on because it is a different form of learning that makes you apply things that you just have learned." (fall 17_6)
>
> "Greatly helped in understanding the material, and showed how to use the knowledge" (fall 17_7)

"These allowed me to understand topics a lot more and get a better understanding of biology in general." (fall 19_1)

"The class activities helped my learning and understanding of the subject." (fall 19_2)

These findings are supported by previous studies reporting increased learning outcomes, higher engagement, decreased academic anxiety, and increased confidence in course material through peer-peer interactions and collaborative learning opportunities (Lord, 2001; Cooper, Downing, & Brownell, 2018).

Limitations

One limitation of the current study's findings lies in the statistical analyses. One primary analysis of performance outcomes was limited to summative assessments (exams) which provide a one-dimensional view of student success. To truly measure success at improving student learning gains and development of higher-order thinking, it might be more informative to explore formative assessments. Secondly, due to the great variety that exists in flipped classroom design, especially with the addition of the LA model, it may be hard to generalize the findings, particularly in non-STEM courses at alternate institutions. Furthermore, the quasi-experimental design prevents true random assignment of subjects into groups and the ability to control for all variables within the study design (i.e., class size, day/time of class meetings, location of class) may result in unequal groups and decreased internal validity. Additionally, there may be reduced external validity of the study due to the "reactive effect" of the intervention (Tuckman & Harper, 2012, p.72). As described by Tuckman and Harper (2012), the reactive or

Hawthorne effect result from the sheer fact there was an intervention, and changes in success outcomes may not be a true measure of the specific of the intervention, therefore, benefits of the interaction may not be "true" but instead represent a "reactive" response (p. 172 -173). As for the structure of the intervention itself, it is impossible to disaggregate the effects of the flipped class design and the influence of the LA model on student success. Finally, the significant increases in response mean for SALG questions addressing the perceived benefit of group work on learning gains after the flipped class intervention may have been exaggerated due to a lack of group work or student's lack of understanding of the group work construct in the pre-intervention sections.

Implications for Practice

Flipped classroom studies often lack sufficient empirical data, focus on student perceptions over learning outcomes, report inconsistent results, or rely on data from a single cohort or very small samples (Langin, et al, 2020). This study provides further data-driven evidence to support the benefit of active learning toward improved student success across multiple sections of a large-enrollment course. Nevertheless, the work is far from complete. Mayer (2004) contents that constructivism in the form of active learning is a pervasive theme within education. However, Mayer (2004) argues that it is desirable for learners to be cognitively active, rather than passive learners, but it is not always necessary for them to be truly active in a behavioral sense. Many students abhor active learning and fail to show substantial learning gains when it is presented as true discovery-based with little guidance offered from a teacher or more advanced peer (Mayer, 2004). Vygotsky drew attention to the importance of social aspects of learning environments through his Zone of Proximal Development (Vygotsky, 1962). Even in a learner-centered environment, the instructor still plays an instrumental role in the learning process serving as a guide to facilitate students' progression through the levels of cognitive development. Active learning for the sake of engagement or attempting to move away from the passive reception of information is an inadequate approach. Mayer (2004) asserts "Instead of depending solely on learning by doing or learning by discussion, the most genuine approach to constructivist learning is learning by thinking." (p. 17). Furthermore, Bransford, Brown, and Cocking (2000) report that research indicates metacognitive approaches to learning favor the transfer of skills and that "transfer is affected by the degree to which people learn with understanding rather than merely memorizing a set of facts or follow a fixed set of procedures" (p. 55). Active Learning may be considered a process for learning, but it is vital for learners to be guided through processes to construct knowledge (Findlay-Thompson & Mombourquette, 2014).

Future Research

The first recommendation for future research would be to obtain more qualitative data. Interviews, rather than just surveys, with both class participants and LAs, would provide richer context and a deeper understanding of how a flipped classroom and the LA program influence student learning. Additionally, a major obstacle when implementing a flipped class design is ensuring students are adequately prepared before attending class. Flexibility and self-pacing may be considered benefits of the flipped class design, but it comes at a cost to students who have less than optimal time management skills. Furthermore, McLean et al (2016) contend those implementing a flipped course design should consider the use of pre-class formative assessments because "students value the opportunity to assess their knowledge in a safe environment". (p. 54). Future directions should include developing measures for monitoring how often and when students view recorded lectures and investigating the implementation of pre-class formative assignments to ensure they are completing the assigned tasks early enough and thoroughly enough to be fully prepared to contribute to group work and complete application-based activities. Furthermore, it is possible that there are other benefits to the flipped class design that were not explored by the limits of this study. It has been argued that the goal of assessing higher-order thinking skills cannot be easily achieved with multiple-choice exams (Darling-Hammond et al., 1995). Recommended next steps should involve developing assessments containing questions specifically designed to adequately assess higher-order thinking skills. Finally, further research is required to address racial inequities and economic disparities related to college readiness and how these factors influence the efficacy of curricular interventions. The Joint Working Group on Improving Underrepresented Minorities assert that curricular interventions should be evidence-based and proven by theory and that the most effective interventions are those which engage students and pique their interest (Estrada et al., 2016). Nevertheless, it is essential that issues of resource disparities be addressed at the program and institutional levels and that program-level interventions be thoroughly researched and continually modified based on the findings of that research (Estrada et al., 2016).

APPENDIX A- ACUE CERTIFICATION

ACUE

American Council on Education

THE ASSOCIATION OF COLLEGE AND UNIVERSITY EDUCATORS AND THE AMERICAN COUNCIL ON EDUCATION

Be it known that

Cynthia Littlejohn

having demonstrated the comprehensive knowledge and skills that constitute the ACUE Effective Practice Framework has been presented with this

Certificate in Effective College Instruction

Recognized on the
17th of April of the year 2022

Ted Mitchell, PhD
President
American Council on Education

Penny MacCormack, EdD
Chief Academic Officer
Association of College and University Educators

ACUE

EFFECTIVE PRACTICE FRAMEWORK

DESIGNING AN EFFECTIVE COURSE AND CLASS
- Establishing Powerful Learning Outcomes
- Aligning Assessments With Course Outcomes
- Aligning Activities and Assignments With Course Outcomes
- Preparing an Effective Syllabus
- Planning an Effective Class Session

ESTABLISHING A PRODUCTIVE LEARNING ENVIRONMENT
- Leading the First Day of Class
- Promoting a Civil Learning Environment
- Connecting With Your Students
- Motivating Your Students
- Engaging Underprepared Students
- Helping Students Persist in Their Studies
- Embracing Diversity in Your Classroom

USING ACTIVE LEARNING TECHNIQUES
- Using Active Learning Techniques in Small Groups
- Using Active Learning Techniques in Large Classes
- Delivering an Effective Lecture
- Planning Effective Class Discussions
- Facilitating Engaging Class Discussions
- Integrating Civic Learning Into Your Course

PROMOTING HIGHER ORDER THINKING
- Providing Clear Directions and Explanations
- Using Concept Maps and Other Visualization Tools
- Teaching Powerful Note-Taking Skills
- Using Advanced Questioning Techniques
- Developing Self-Directed Learners

ASSESSING TO INFORM INSTRUCTION AND PROMOTE LEARNING
- Developing Fair, Consistent, and Transparent Grading Practices
- Developing and Using Rubrics and Checklists
- Providing Useful Feedback
- Checking for Student Understanding
- Using Student Achievement and Feedback to Improve Your Teaching

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RECORD OF PROGRESS

Name Cynthia Littlejohn
Date 04/17/2022

COMPETENCY	MODULE	STATUS
Designing an Effective Course and Class	Ensuring Learner-Centered Course Outcomes	Complete
	Designing Aligned Assessments and Assignments	Complete
	Aligning Learning Experiences with Course Outcomes	Complete
	Preparing an Inclusive Syllabus	Complete
Establishing a Productive Learning Environment	Leading a Productive First Day	Complete
	Promoting a Civil Learning Environment	Complete
	Motivating Your Students	Complete
	Ensuring Equitable Access to Learning	Complete
	Helping Students Persist in Their Studies	Complete
	Embracing Diversity in Your Learning Environment	Complete
Using Active Learning Strategies	Using Groups to Ensure Active Learning	Complete
	Using the Active Learning Cycle	Complete
	Developing Effective Class Sessions and Lectures	Complete
	Planning Effective Discussions	Complete
	Facilitating Engaging Discussions	Complete
Promoting Higher Order Thinking	Providing Clear Directions and Explanations	Complete
	Using Concept Maps and Other Visualization Tools	Complete
	Teaching Powerful Note-Taking Skills	Complete
	Using Advanced Questioning	Complete
	Developing Self-Directed Learners	Complete
Assessing to Inform Instruction and Promote Learning	Developing Equitable Grading Practices	Complete
	Creating Equity with Checklists and Rubrics	Complete
	Providing Useful Feedback	Complete
	Checking for Student Understanding	Complete
	Using Student Achievement and Feedback to Improve Your Teaching	Complete

APPENDIX B - IRB APPROVAL

Office *of* Research Integrity

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Modification Institutional Review Board Approval

The University of Southern Mississippi's Office of Research Integrity has?received the notice of your modification for your submission *Impact of an Active Learning Intervention on Student Success and Persistence in an Introductory-level Undergraduate Biology Course.* (IRB #:21-418).

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI via the Incident submission on InfoEd IRB.
- The period of approval is twelve months. An application for renewal must be submitted for projects exceeding twelve months.

PROTOCOL NUMBER:	21-418
PROJECT TITLE:	Impact of an Active Learning Intervention on Student Success and Persistence in an Introductory-level Undergraduate Biology Course.
SCHOOL/PROGRAM	Center for STEM Education
RESEARCHERS:	PI: Cynthia Littlejohn Investigators: Littlejohn, Cynthia~Schaefer, Jacob~
IRB COMMITTEE ACTION:	Approved
CATEGORY:	Exempt Category
APPROVAL STARTING:	26-Jan-2022

Donald Sacco, Jr.

Donald Sacco, Ph.D.
Institutional Review Board Chairperson

Gene Expression

Chapter Outline:

- **Overview of Gene Expression**
- **Transcription**
- **RNA Processing in Eukaryotes**
- **The Genetic Code**
- **Translation**

- Information of DNA in form of specific sequences of nucleotides
  - **Genes**
- Inherited genes lead to specific traits by controlling protein synthesis
  - Proteins link **genotype** (genome) to **phenotype** **(**proteome**)**

- **Gene expression**
  - process by which DNA directs protein synthesis
  - includes two stages: transcription and translation

Central Dogma of Molecular Biology

DNA —transcribed→ RNA —translated→ Proteins

- RNA is intermediate between genes and proteins

How do genes determine traits?

- Structural genes code for **polypeptides**
- Polypeptides act as a **protein** to play some role in the cell
- Activities of proteins determine the **structure and function** of cells
- Cellular activity in an organism determines **traits or characteristics**

- The linear order of bases in a gene specifies the amino acid sequence --the primary structure --of a protein, which in turn specifies that protein's three -dimensional conformation and function in the cell

Three stages of transcription

Initiation ⟶ Elongation ⟶ Termination

1. Initiation

– **Promoters -** Upstream from gene where RNA polymerase binds

– **TATA box** in eukaryotes

–**Transcription factors** required for RNA polymerase to recognize and bind to promoter

2. Elongation

- RNA polymerase synthesizes RNA
- **Template strand** used for mRNA transcription
  - **Coding strand** is not used
- Synthesized 5' to 3'
- **Uracil** substituted for thymine

3. Termination

- RNA polymerase reaches **termination sequence**
- Causes both the polymerase and newly -made RNA transcript to dissociate from DNA

RNA Processing in Eukaryotes

- Bacterial mRNAs can be translated immediately
- Eukaryotes create pre -mRNA that requires processing into mRNA
  - **Introns** – non-coding sequences
  - **Exons** – coding sequences

- **Splicing** – removal of introns
- **Spliceosome** – removes introns
  - Composed of snRNPs (small nuclear RNA and proteins)
  - **Alternative splicing**
  - **Exon shuffling**

Additional RNA processing

- **Capping**
  - Modified guanosine attached to 5’ end
  - Needed for mRNA to exit nucleus and bind ribosome
- **Poly A tail**
  - 100-200 adenine nucleotides added to3’ end
  - Increases stability and lifespan in cytosol

The Genetic Code

- **Genetic code** – sequence of bases in an mRNA molecule
  - **triplet code**

- Read in groups of three nucleotide bases
  - **codons**
  - Specify a particular **amino acid**

Characteristics of the genetic code

- **Linear triplet code**
  - 64 possible codons
  - 61 sense and 3 nonsense (stop) codons
- **Unambiguous** but **Redundant**
- **No overlap** of codons
  - Specific reading frame
- **Universal**

- mRNA has 5’ ribosomal-binding site
- Start codon usually AUG
- Typical polypeptide is a few hundred amino acids in length
- Stop codons (nonsense codons)
  - UAA, UAG or UGA

- mRNA
  - **Codon** – set of 3 RNA nucleotides
  - T of DNA substituted for U of RNA

- tRNA
  - **Anticodon** – 3 RNA nucleotide part of tRNA molecule
  - Allows complementary binding of tRNA to mRNA codon

The Machinery of Translation

- Requires many components
  - mRNA
  - tRNA
  - ribosomes
  - translation factors
- Most cells use a substantial amount of energy on translation

tRNA

- Different tRNA molecules encoded by different genes
  - $tRNA^{Ser}$ carries serine
- Common features
  - Folded single strand
  - Anticodon
  - Amino acid attachment site

Structure Directs Function

- The structure of tRNA has two functional sites: a 3’ **single-stranded region** where an amino acid is attached and an **anticodon** that binds to a codon in mRNA.

Ribosomes

- two subunits (large and small) made of proteins and**ribosomal RNA (rRNA)**

- Three binding sites for tRNA:
  - **P site** holds tRNA that carries the growing polypeptide chain
  - **A site** holds tRNA that carries the next amino acid to be added to the chain
  - **E site** is exit site, where discharged tRNAs leave the ribosome

The Stages of Translation

1. **Initiation**
   – mRNA, first tRNA and ribosomal subunits assemble
2. **Elongation**
   – Synthesis from **start codon** to **stop codon**
3. **Termination**
   – Complex disassembles at stop codon releasing the completed polypeptide

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BSC 110 **Transcription Translation Activity Part 1**

	DNA	**RNA**
Basic Function	Provides instructions for making ____________________________	Delivers the message and components to the _______________ where proteins (polypeptides) are assembled
Type of Organic Molecule		
# of Strands	___________________ Stranded	_______________ Stranded
Sugar		
Nitrogen Bases		
Base Pair Rules		

Complete the CENTRAL DOGMA of molecular biology	**DNA** → (___________________) → **RNA** → (_________________)→ **PROTEIN**
Fill in the blanks	A structural gene is a linear sequence of _________________________ that codes for a specific linear sequence of _____________ _______________which results in the expression of a particular trait. ________________________ (genes present in an organism) is linked to ________________________ (actual traits expressed) by the _____________________ produced by that organism.

Using the DNA molecule below, transcribe an mRNA. Be sure to label 5` & 3` ends.

DNA **5`- A – T – C – C – A – T – C – G – A – C - 3`**

DNA 3`**- T – A – G – G – T – A – G – C – T – G - 5`**

mRNA ____

Which strand of DNA above did you use as the template for transcribing your mRNA and why did you select that strand?

Where in a eukaryotic cell does transcription take place? Why can transcription only happen there?

Briefly summarize the three steps of transcription of a structural gene (you should discuss the promoter, transcription factors, RNA polymerase, and terminator).

1. Initiation

2. Elongation

3. Termination

Once an mRNA is transcribed in a eukaryote, it is processed before it is sent out to the ribosome to be translated. **Briefly** summarize what happens during this mRNA processing (post-transcriptional modification).

The human genome contains about 25,000 structural genes and yet a human cell can produce about 100,000 different proteins. Propose an explanation for how this is possible.

BSC 110 Transcription/Translation Activity Part 2

Diagram the steps of the central dogma of molecular biology (genetic expression).

____________________RNA (mRNA)	• Carries the message for protein (polypeptide) assembly in the form of a series of three letter "words" called ________________.
___________________RNA (tRNA)	• Has an ___________________ which allows it to deliver the correct _____________ _____________ to the ribosome to assemble the polypeptide chain.
____________________RNA (rRNA)	• Makes up the ______________________which reads and displays the RNA message and creates the peptide bonds between amino acids to form the polypeptide (primary structure of a protein).

Using the correct DNA strand as a template, transcribe a piece of mRNA. Then write the correct tRNA anti-codon under each mRNA codon. Use the codon table in your textbook to determine the amino acid (A.A.) sequence (list abbreviations from the table). Put dashes *between mRNA codons* to indicate the correct reading frame.

DNA 5` A T G G G A T T C A G G A T A T A A 3`
3` T A C C C T A A G T C C T A T A T T 5`

mRNA

---

tRNA

A.A.

Briefly explain why the genetic code is considered to be unambiguous and redundant.

Mutations are changes in a DNA sequence. How could the redundancy of the genetic code allow for a silent mutation – a change in genotype that has no impact on phenotype?

Where in a eukaryotic cell does transcription take place? Where in a eukaryotic cell does translation take place?

Briefly summarize the three steps of translation of a structural gene (you should discuss the large and small ribosomal subunits, mRNA, tRNA, start codon, A site, P site, E site, and stop codon)

1. Initiation

2. Elongation

3. Termination

During translation, the start codon is positioned at which ribosome site (E, P, or A)?

Aside from the initiator tRNA, all new tRNAs enter at which ribosome site (E, P, or A)?

When the ribosome moves to the next codon, the tRNA that no longer has an amino acid attached to it moves to which ribosome site (E, P, or A)?

Translation is complete when a stop codon enters at which ribosome site (E, P, or A)?

Do you think it is likely that every cell in an individual will express all 25,000 genes and produce all the 100,000 possible proteins? Why or Why not? **Explain your answer.**

APPENDIX E - SALG SURVEY

Table A1.

Student Assessment of Learning Gains

	0 = not applicable	1 = no help	2 = little help	3 = moderate help	4 = much help	5 = great help
The Class Overall/ Section 1 of 7						
How the class topics, activities, reading, and assignments fit together						
The pace of the class						
Class Activities/ Section 2 of 7						
Participating in discussions during class						
Participating in group work during class						
Doing hands-on class activities						
Assignments, graded activities, and tests/ Section 3 of 7						
Graded assignments (overall) in this class						
The number and spacing of tests						
The way the grading system helped me understand what I needed to work on						
The feedback on my work received after tests or assignments						
The information you were given/Section 4 of 7						
Explanation of how the class activities, reading and assignments related to each other						
Explanation given by instructor of how to learn or study the materials						
Explanation of why the class focused on the topics presented						
Support for you as an individual learner/Section 5 of 7						
Working with peers during class						
Working with peers outside of class						

Table A1 (continued).

As a result of your work in this class, what gains did you make in your UNDERSTANDING of each of the following?
Your understanding of class content/Section 6 of 7
The main concepts explored in this class
The relationships between the main concepts
As a result of your work in this class, what GAINS did you make in the following?
Class impact on your attitudes/Section 7 of 7
Willingness to seek help from others (teacher, peers, TA) when working on academic problems

Please comment on how the class activities (discussions, group work, and/or hands-on class activities) helped your learning.

APPENDIX F - SALG OPEN-ENDED RESPONSES

Student Assessment of Learning Gains Survey Open-ended Responses

Fall 2015 (n=34)

- I love how she kept my attention throughout class
- helped further clarify the material
- The group discussions helped me the most because it helped me retain the information better
- Professor Littlejohn's lectures were excellent. Her various, detailed examples made me understand the material better. The class did not participate in much class discussion, however, she did ask questions often and the class would respond. Those also proved to be helpful in learning the material.
- It didn't really help me understand the material
- I learn best by actively doing projects or activities. For me, lectures are harder for me to process.
- The degree of how group work helped depended on how engaged others in the group were (as in lab). Discussion is always good, we learn from each other's questions and answers. Hands on is the best for me, it helps it go from information to something I understand.
- The discussions helped me learn because my professor knows what she is talking about and breaks it down for us to where we can understand it.
- Before every test, we had the opportunity to get in a group and study for extra credit on the test
- We did not have many hands-on classroom activities. I'm actually not sure that we had any at all, but this class was very productive and very informative.
- There were none
- The in depth lectures helped me to better understand the topics we covered.
- everything that we go over is really helpful
- We did not do any group activities in class. The lectures helped some but it is hard to pay attention is a class period that lasted so long. The best thing for me is to read the book.
- In class hands on activities and discussions were not apart of the course.
- The most helpful group activity was the biology study group which in return counted for a few bonus points.
- The online assignments helped me to better understand test questions.
- Discussing the different topics in class helps me further understand the information more. It goes deeper into the actual information. We really didn't do group work, and hand on class activity.
- These types of assignments do not really help. They are sometimes cool to partake in but most times not.
- I didn't say or hear much from others
- The printed power points and the lecture really benefited.
- learning in small groups works better for me

- I enjoyed this class because I loved the way my teacher taught. She made it easy to understand, and she made it very interesting.
- There was no group work or hand on class activities because of the size of the class. There was discussion about topics we did not understand and many review discussions.
- After completing a chapter, we were allowed to ask questions on anything we didn't understand throughout the lecture which was a major component in helping me learn at best.
- interaction with the teacher was extremely helpful because of her presentation
- group work= study group. study group introduced me to other outlooks and new perspectives on how to study and take notes
- We never had much group work unless you decided to outside of class. Understanding because the class was so big.
- Great discussions and group work.
- I thought the pace was nice because it gave me time to stay caught up without feeling overwhelmed. Also, I thought the pictures and figures used were helpful to see it drawn out. Answering questions in class was helpful as well.
- They helped improve my study habits and grades.
- Class discussions helped me to familiarize the material due to repetition and online exercises.
- there were no in class activities
- Personally, I learn best by participating in activities rather than listening to lectures. However, the lectures in class were very helpful and not at all boring.
- Group work with my study group greatly helped my test performance in the class
- It was all mostly lecture honestly.

Fall 2016 (n=32)

- Discussions about various things the class didn't understand as a whole helped the most.
- They help me understand topics better
- I really liked how we would write stuff on a paper that we did not understand and then Professor Little john would call on us to ask what it was. Then, she would explain it to us. Those really helped me understand some things that I didn't understand when she taught it in lecture.
- Hearing other people's questions usually helps me remember things.
- These activities improved my understanding of the information in each chapter. It allowed for me to partner with other students in my class and teach the information that we were knowledgeable about to another student. These class activities definitely helped my grade in the class.
- It allowed me to bounce ideas off of others students, and see their perspectives.
- Being able to get ideas from others and having time to actually see what you know and what you do not know helps a lot with the learning process.

- The discussions were very helpful in preparing me for the tests! I appreciated the activities in order for us to understand difficult topics better. Dr. Littlejohn did a great job teaching each chapter, and she made the lessons very interesting with her examples!
- We did not do any hands on.
- We didn't do much hands on work, but when we did it was beneficial because it pertained to specific chapters we were learning.
- they allowed me to listen to how other people thought on numerous points; gave me alternate ways to understand material
- They made me talk about the subject more which helped me retain the information better.
- The discussions and the group work help the most with getting others explanation of things. Sometimes only hearing one way over and over might not understand until someone else explains it in a different way.
- The class did not have very many hands-on activities and I don't think there would be much time to do them. With that being said I don't think they would help all that much for me but they might for others.
- It helped to understand things better, let's say if a student asked a question aloud the professor gave a well thought out answer right off the back in response to the question.
- We had little hands-on class activities and group work if any. The one thing that helped me learn were the study groups I had after class. Encouraging the study groups absolutely helped me to learn and be motivated to do so in such way.
- Professor Littlejohn, did an amazing job she kept us entertained and interactive with one another through class activities! Great job keep up the good work!
- I enjoyed group work because I was able to learn from classmates and have them learn from me.
- The discussions helped me on information that was not clear. The group work also helped me learn new things from my fellow classmates about the lesson and I also was able to share my knowledge to help them.
- The class discussions and relatable topics that our teacher used to explain things really helped me to understand the material.
- I was able to discuss with my peers on topics I did not understand, which helped me gain a better understanding.
- There weren't really any. Everything that was related to group work or hands-on was done out of class on our own time - which is hard to manage for people with conflicting schedules. The discussions we had were basically to recall some minor things and explain them, something we could look up in our notes on our own later, and was of no value to learning other than to hear it repeated for the 5th time that class period - to which many people don't listen anyway.
- I remember more information when we do group discussions.
- Group discussions helped me with my learning by showing me other ways to look at things. People in a group can show to ways and techniques to remember

different subjects. Some people in my group discussions would also explain topics differently than my professor, and it's easier for me to understand.

- It helped me in a way that if I did not know something or was confused on something peers could give insight on what I needed to know, and discussions and hands-on activities allowed me to talk with classmates and trade information that we knew and obtain information that we did not know before.
- it helped me get different views on different topics.
- questions in the beginning of class helped a little
- It helped me by comparing what I knew and learned from the lectures to what others in the class gained by the same lecture. If didn't understand something in the lecture, there was a good chance that someone in my group did.
- The hands-on activities in my lab helped me to understand the concepts better, and the group discussions helped because talking about the material helped me to understand it better.
- extra credit was good
- Other students were able to help me understand the material from their perspective
- I could hear things that I may have missed in class and heard other people's way of understanding topics that I did not understand

Fall 2017*(*n=39*)*

- The group work helps me tremendously. It seems simple while you discuss it, but sometimes on our own, it is much more difficult. So being able to talk it out with others is a nice way to figure it out with help rather than figuring out how hard it is alone on the test.
- I am an active learner. Being able to view the lectures online before class helped me to actually know the information that was being lectured. By knowing the information before class, I was able to assure my knowledge on the topic. The last thirty minutes of class we would do a group worksheet, and this helped me actually apply the knowledge that I learned and get even more reassurance on how well I know the topic with the help of my group. In the last five minutes of class, we would take a quiz. The quiz was another method of rearranging, but for how well I attainted all the given information on my own. I really enjoyed the way the teacher incorporated all of the different learning styles to help every style of learning have an opportunity to help them succeed.
- Having conversations about the topics helps me process the information better
- The activities were helpful, but I would prefer not to have to do them with a group. I think it would be better if we did them individually and then went over the answers at the end of class. Some people in your group just want to copy your answers and do not help.
- Working with others and getting a different explanation makes it easier to grasp concepts
- If I was ever confused most of the time my questions were answered with one of the activities or the lecture.

- By talking about it helped me get it stuck in my brain
- It allowed me to “test” what I knew and helped me focus on what I needed help on
- It helps me really apply the things we are learning
- Classmates get to put their minds together to come up with the best answer
- It allowed for better understanding.
- The group work really helped my learning because I got to see how other people's ideas and my ideas can come together as one and still get a great answer. Also, we studied outside of the classroom which really helped as well.
- I learn better by hearing things verbally, but some of the activities helped me apply the information hands-on which helped but some topics needed more lecture time.
- Participation in class is very helpful to the course and the overall learning experience for myself.
- I liked the activities we did without using our notes to test our knowledge.
- The class activities really helped a lot. I could tell when we didn't have a class activity that it hurt me in learning the material even more.
- It breaks down the material, and me and my classmates can help each other. Also, the TA's and Ms. Littlejohn herself helps the class out during the activity.
- It was very helpful to do hands-on because it is a different form of learning that makes you apply things that you just have learned.
- I think that the group work was the most beneficial for me. I was able to learn answers to questions that I did not know rather quickly.
- It gave me a chance to listen to someone else explain a topic if I didn't understand it after the lecture. The hands-on activities helped me really understand why and how certain things work.
- I enjoy reading about a topic, hearing the lecture, and then doing an activity. It reinforces all of the material covered and allows for a better understanding.
- the activities helped but group work did little for me
- We usually get a group activity and we get to talk the questions out with our classmates and it helps a lot because you always know if you’re right or wrong right away.
- The class discussions, activities, and quizzes have extremely helped me retain the material.
- I feel as though the discussions in class helped me learn the most. The thorough explanations that Ms. Littlejohn made enabled me to more clearly visualize some of the biological mechanisms and structures.
- The group work helped me understand concepts in class.
- it was much help
- Discussing with other students advocates communication skills and properly gives feedback on the correct answer and why.
- The group work was very beneficial because sometimes students can simplify it more than teachers since teachers are so educated in the subject.

- The class activities helped my learning by being able to work in groups. Oftentimes, it's difficult to ask questions out loud to the professor, but by being in a small group it is easier to ask those questions. The LA's were also a great help, in answering any questions that my group (and others) had.
- They didn't because I wasn't taught the information before being asked to do the activity
- It made the information applicable and was a helpful review.
- The activities allowed for me to engage in the content with peers and it helped me understand the content having multiple minds thinking about the work.
- It allowed for me to work with what we were learning instead of just hearing about it. Being able to do this greatly helped with my ability to understand the content.
- Greatly helped in understanding the material, and showed how to use the knowledge.
- We lecture then the activities show what we learn in a psychical way to see if we paid attention and understood
- My learning style has never been auditory, so being able to have worksheets and time to be able to ask for help was very beneficial for me.
- The activities were extremely beneficial.
- Each class activity thoroughly covered the information learned that day, which reinforced the learning.

Fall 2018 (n=88)

- The handouts were a great use in studying for the exams and quizzes. Also, the learn smart homework really helped.
- They helped my learning because I'm a "hands-on" learner. It put everything in perspective.
- Someone in the group always *understood more than I did and they explained the concept in simpler terms than the teacher*
- The work has the perfect amount to force the knowledge onto you
- The active learning helped me to better understand what was going on around me. I felt like was able to learn more.
- helped more than a normal lecture
- You got to work with classmates.
- It kept my attention. It was a lot better and I learned more compared to a lecture.
- Discussions cleared up misunderstood info. Group work did not help. Hands-on activities helped me a lot.
- Each of us are giving an opportunity and express different ideas.
- made it applicable
- The group work allowed me to receive one-on-one help from my peers.
- It helped to bounce ideas off group members.
- The class activities were VERY helpful in ensuring I felt comfortable with the material we were learning.

- make me remember better, and apply
- I liked working in a group; it made me learn better.
- Doing group work/hands-on activities helps apply what was discussed in lectures and increases understanding.
- It made me think and apply what I knew.
- more in-class lectures instead of online
- They help me be able to talk to others to get more information.
- By talking through the problems it ensured that everyone understood and those who understood got more practice by explaining.
- I am a hands-on learner and usually activities help me to visually understand concepts along with mentally understanding.
- The class activities helped a lot. I liked how the class was structured. Thanks for a great semester!
- The class activities help my learning by giving me more knowledge about the information we was going over.
- It helped to work with other individuals to see/figure out different ways to study and gain knowledge.
- Having to write handwritten notes did not help me learn. I do not learn or study the best this way. I learn better listening and reading the textbook. Therefore, grading for notes that some people do not learn from is not inclusive of all the students in class.
- Helped me be able to see and do things on my own and not just watch it on the computer. Best teacher this semester.
- It helped me get a better understanding of the work since I was actually doing work on it instead of listening to a lecture.
- I liked working in groups because if I didn't know something, someone in my group did. The activities helped me learn the materials.
- With the group I was with I gained more understanding during activities since each of us brought strengths and helped each other understand/learn.
- The class activities helped me learn best because I am a hands-on learner.
- They helped me by learning better for the test because others helped with understanding.
- It allowed for repeated application of knowledge that encouraged commitment to memory.
- It helped me to gain more information from someone else other than myself.
- Class activities helped with vocabulary and not only knowing the definition without knowing how something works or why it does so.
- I learn better with hands-on activities, so doing so many activities really helped me.
- It is more interesting to do hands on than it is to just sit and listen.
- Talking to other people about things I did not understand and getting it explained different ways helped to understand it.
- Group work helped a lot with better understanding
- The class activities were good study tools.

- It helped to explain things and hear things explained differently.
- We were forced to talk things out and therefore forced to learn the material. :)
- Being able to talk with one another allowed me to get so much more help and do better in the class.
- They were very effective and helpful.
- They helped because I would understand from my peers, as well as the LAs.
- Activities were designed to help students learn the important info needed for tests.
- The hands-on activities and group work help if you don't like talking in front of class, the other students have a possibility to know something you don't. The discussions help if you aren't an auditory learner.
- I'm a visual learner, so when we did hands-on activities it helped me learn the material better.
- Group work/activities made it easier to grasp concepts.
- The discussions were great for learning in class. Hands-on class activities were great for group learning and interacting with classmates.
- I really benefitted from working in groups and having a group to study with.
- It allowed me to understand more information and establish relationships with others who can help teach me the content.
- I got a better understanding of our lesson.
- Allowed me to actively engage in topic and figure things out on my own.
- Doing these different activities helped test my knowledge and it was a great help when studying.
- Group work helped me figure out different ways to learn material. Hands-on activities were very helpful when trying to understand the concepts.
- I'm a hands on learner so doing hands on activities such as the mitosis and meiosis I and II project helped me learn the phases better.
- I loved that there were multiple resources (textbook, online assignments, extra credit, group activities, and ESPECIALLY the recorded lectures) to help us succeed. I am a slow learner, so the hands-on coupled with at-home exercises were helpful. They really helped me out a lot!
- Discussions and group work deemed extremely beneficial to my learning as I problem-solved and brainstormed with others within my group.
- helped me understand the topics we were doing in class
- The class activities help me get a better understanding on the topics we discussed. And the in-class quizzes showed me just how much I knew. That way I knew what I needed to study.
- I am a tactile learner, so it was easier to watch what I was learning and do hands on things to show my knowledge.
- These hands-on activities are like an insight to the test, and they gave us an opportunity to ask questions to TAs/LAs individually.
- The groups division was a smart idea since the class has over 117 students.
- Help me understand the lecture more
- The activities helped me learn because my group knew things that I didn't.

- By being so hands on and actively learning with your peers it helps you improve on your understandings on certain topics
- Other students provide useful ways to learn things and to remember them.
- The class was very informative.
- Activities helped better visualize concepts.
- Overall the class setting was fine but the last of personal attention was unfortunate. I am aware that is very, very difficult to accomplish because of the sheer number of students.
- Activities helped being hands on
- The activities, study groups, and lectures were very beneficial.
- The class activities helped my learning because it helped me to comprehend and understand the material rather Han just memorizing it.
- loved doing group work. It made coming to class 10x more helpful. Really helped me have a better understanding of the material.
- I think the way the class is structured really helps the student to learn properly. The recorded lecture offer a lot of help at the time to study for exams.
- Bouncing ideas off of each other and having to voice the thought process is helpful.
- They all fit together well and helped me have a full understanding of the topics being discussed.
- Group work really helped me because they could explain difficult concepts to me.
- The group work on the activities provided a great amount of help when learning concepts
- They allowed my classmates and I to work together and collaborate to better understand each topic.
- It helped me better understand topics I was confused about.
- the group work was the best
- the discussions didn't do much
- The activities helped a lot while learning throughout the class. Really liked the active learning and groupwork; super beneficial to learning.
- The group learning really helped me a lot in this class because we were all able to share ideas.
- activities helped reinforce lectures
- the group assignments helped reinforce what was discussed in the recorded lectures.

Fall 2019: (n=38)

- I appreciate my teachers' ability to marry a run class environment that is effective in lesson plans. the groups allowed me to explain concepts I wasn't clear on and be challenged to think further than the textbook.
- Activities helped me understand better.
- It was physical. Doing group work helped when you could have extra help if needed. Everyone had different opinions and ideas.

- LOVED the class!
- The stuff we had to study outside of class was overwhelming.
- I really liked my group. We all worked together and studied with each other often.
- I enjoyed the participation portion of the class and I feel like it really helped me understand the topics better.
- my favorite class
- It helped me better understand the lesson to complete the activity
- It would be more helpful to do lectures in class so you are more engaged.
- activities in class helped me understand the topics better.
- It only helped to a certain extent
- Discussions were redundant, but group work and hands-on activities helped me to understand the material.
- It helped me a LOT, you'll probably see me in MICRO soon. Thank you :)
- the activities and quizzes made me come more prepared for class.
- I was able to work with my peers and put our knowledge together for a better understanding of the topics as well as the hands-on activities.
- These allowed me to understand topics a lot more and get a better understanding of biology in general.
- The class activities helped my learning and understanding of the subject.
- Made learning fun
- This helped because I am a hands-on learner.
- every class activity helped me learn because it was always so interactive.
- Littlejohn is an amazing teacher! She tries her best to get us the info we need for our test. I am excited to take her again next semester.
- Helped by working together with classmates and understanding not just a teacher telling you the answer if you didn't know.
- This helped me better understand what was going on that just reading the chapters. However, if my group at my table didn't know what was going on then it wasn't much help.
- I'm an on hands learner.
- helped understand the lectures better
- Doing the hands-on activities assured me that I know what was going on before leaving.
- Lab did not fit the lecture at all. Different concepts than what we were learning in lectures.
- I liked how the class was formatted in the way that we taught ourselves.
- I was able to understand the subjects better
- Everything worked in sync and helped a lot.
- I feel like the way the class is set up helped a lot learning wise and made the class easiest to learn.
- It was kind of scary to ask the professor questions because it seems like she would get mad at us for not knowing the answer.
- It helped solidify the class material and helped with studying for exams.

- The groups had to work together to figure out the correct answer rather than writing for the professor just give us the answer.
- It helped me learn by holding me responsible for my understanding in the class.
- I learn best by being able to communicate concepts and ideas with others so discussion and group work were nice. Hands-on class activities further encourage active learning.
- Group work and hands-on activities really helped.

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