Effects of Peer Instruction on State College Student Achievement in an Introductory Biology Unit in Genetics

by

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ABSTRACT

TITLE: The Effect of Using Peer Instruction on State College Student Achievement in an Introductory Biology Unit in Genetics

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The purpose of this study was to examine the effects of Peer Instruction (PI) in a state college biology classroom. Students discussed biological concepts in the area of genetics among their peers during class time. Conceptual questions were delivered to the student in the form of ConceptTests, conceptual questions designed to uncover students’ misconceptions in the material. Students first answered a question projected from the computer to an overhead screen on their own. Depending on the percentage of students that answered correctly, students then discussed their answers with their peers (PI). These discussions allowed students to uncover their misunderstandings in the material by asking them to think about what they know and what they don’t know. Students’ initial and secondary responses to the related questions gave the instructor a real time instant view of the collective class’ conceptual understanding of concepts being covered.

This study was a quasi-experimental, pretest-posttest, control group design. The sample consisted of 134 students enrolled in General Biology (BSCC 1010) at Eastern Florida State College (EFSC) in Palm Bay, Florida. Both control N = 62 and experimental groups N = 72 were comprised of whole intact classes during the
Fall 2014 semester. The control groups received traditional lecture content during the course of the study. They had access to conceptual questions but they were not used in a Peer Instruction format during class time. A statistical analysis was conducted after the completion of pre-tests and posttests during the Fall 2014 semester. Although there was an increase in test scores in the experimental group compared to the control, the results were not significant with p = 0.0687 at an alpha level of .05. No significant difference was found in retention p= 0.5954, gender p = 0.4487 or past science coursework p = 0.6695 between classes that engaged in PI and classes that were taught in traditional lecture-based classes. There were, however, significant differences in correct answers on the individual ConcepTests between the first and second time they answered questions after participating in Peer Instruction, p = .0008.
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Dedication

This dissertation is dedicated to the ones who challenge my mind, fill my heart, and touch my soul…

To my family… Jeff, Lily and Nicholas. You inspire me to be the best person I can be in all aspects of my life. I love you doesn’t cover how deeply I feel for you. First and foremost, I dedicate this dissertation to you.

To my Great Aunt, Jessie Emerald Jacks, born in 1901. You lost your mom when you were a teenager and had to drop out of high school to help my Great Granddaddy Jacks raise my Granddaddy, Sterling Jacks, my Uncle Ora, my beautiful Aunt Mildred, and the best of all cooks and card sharks, my Aunt Edna. You gave up your education to be there for your family. Now, a century later, I am the first Jacks to earn a Ph.D. This could have and should have been you, if only you had the same opportunity. I miss you every day.

To my Nana and my Granddaddy, you live in my heart and I am so blessed to still have you with me on this earth. I treasure you both.

…Finally to my parents and your beautiful minds, this is for you.
CHAPTER 1

Introduction

Background and Purpose

**Background.** The world around us is ever-changing and educators, regardless of their setting, must adapt their instruction to meet the needs of 21st century learners. For example, President Barak Obama remarked on a complete and competitive American Education, “I'm calling on our nation's governors and state education chiefs to develop standards and assessments that don't simply measure whether students can fill in a bubble on a test, but whether they possess 21st century skills like problem-solving and critical thinking and entrepreneurship and creativity” (2009).

In the past a student’s success was based on the amount of information they could memorize, however in today’s information age, conceptual knowledge is more important, (Huitt, 2007). Facts can simply be obtained from the internet while the understanding of concepts is the basis for students’ success, both in the classroom and the real world (Knight & Wood, 2005).

Traditional lecture-based teaching has been the main method of instruction for centuries. While this approach to instruction may have seemed effective in its time, it is not necessarily the best way to reach today’s scholars (Lambert, 2012). Many instructors were taught with the traditional approach and flourished with this
mode of delivery; however, limitations of lecturing have been the sources of debate for decades (Gedeon, 1997). In the late 1970’s a physics professor and a graduate student at Arizona State University noticed a problem with students’ conceptual understanding of the material. Students could easily memorize equations; however they did not understand the concepts that drove them. Students’ preconceived notions about physics were getting in the way of their conceptual understanding of the material being presented and by time the instructors realized, it was too late (Halloun & Hestenes, 1985). Poor scores on qualitative tests raised red flags regarding the effectiveness of lecturing. Traditional teaching methods seemed to only be working for about 10 percent of their students and they suspected that the same10 percent could probably learn the material on their own, without any instruction. They developed an instrument known as the Force Concept Inventory (FCI) that tested a more qualitative and conceptual understanding of physics problems. They administered the FCI as a pretest/posttest to seven introductory physics classes and found only 14 percent learning gains from the beginning to the end of the course (Halloun & Hestenes, 1985). In the early 1990’s the results inspired a Harvard University physics professor to try these tests with his students.

Harvard professor, Eric Mazur, firmly believes that it is the challenge to all educators in the 21st century to find new ways to reach more students. As an undergraduate he was an astronomy student that was disenchanted by the
memorization of countless facts. He moved to the area of physics where he was once again taught by lecturing and tests. As a professor he too used a traditional mode of instruction. After reading studies conducted in the area of physics by Hestenes, Mazur took this challenge by creating a mode of instruction to help students learn more efficiently than they ever have before (Hanford, 2011). Mazur began using an interactive engagement teaching technique he coined Peer Instruction (PI) with his non-physics majors calculus-based and algebra-based physics courses in the early 1990’s. PI encourages interactive engagement by modifying traditional lecture format to include questions that engage students and uncover difficulties with the material. This was done by interspersing the presentation of course material with related conceptual questions, called ConcepTests (Mazur et al., 2002). Students were provided with opportunities for conceptual change allowing students to reconstruct and internalize their knowledge.

The basic premise of PI is that students need the opportunity to discuss science concepts with their peers. In addition, instructors need timely feedback on what their students understand. Class time is given for students to explore their understanding of the material by participating in guided scientific discussion. Instructors are able to gain valuable feedback by listening to these conversations. Concrete feedback is received from all students in the form of a ConcepTest to reveal their misconceptions (Crouch & Mazur, 2001).
**Purpose.** The purpose of this study was to examine the effect of using Peer Instruction on State College students’ achievement in an introductory genetics unit in a first year biology course. There have been many studies by Mazur in the area of physics that address Peer Instruction as an alternative teaching technique to enhance student learning of difficult concepts in a first year physics course; however there has been limited research in the area of biology using PI. The study was based on Mazur (1991) and his findings of PI in the area of physics and was applied to the biological sciences. Knight and Wood (2005) documented partially incorporating interactive teaching techniques to include PI in their University of Colorado Biology classes. PI was one of many variables used as interactive engagement techniques in their study. Other science disciplines in the biological sciences have answered surveys about their experiences with using PI, however, at the time of this study, the researcher was not able to find any publications of their results in the classroom.

A conceptual assessment in the area of biology was administered as pretest/posttest, based on Fagen (2003), and was used to compare PI students’ and traditional students’ achievement in biology. Students in the treatment group actively engaged in their own learning by discovering and correcting their misunderstanding of the material. This was done by interspersing lectures with conceptual questions, in the form of ConcepTests. A ConcepTest, according Eric
Mazur’s book: Peer Instruction: A User’s Manual are “short conceptual questions on the subject being discussed.” In this case students were being asked to think about what they knew and what they don’t know in the area of Genetics. Students would first answer the conceptual question on their own. The results were seen immediately by the instructor through the use of educational clickers that provided an instant view on the corresponding computer monitor of how many students answered correctly. Depending on the percentages of students who answered correctly the question would be given again. Anything less than 80 percent correct would require that the students turn to a pre-determined group to discuss their answers. After group discussion, each student resent their responses individually allowing the instructor to see the learning gains that occurred between the first and second submission of answers. These conceptual questions gave the students the opportunity to explore genetics concepts in a setting that is risk free since their grade was not hindered by answering the question incorrectly. Students, however, received a small amount of credit for participating consistently during the unit. A non-competitive atmosphere was established by using absolute scales as opposed to grading on a curve. This was to prevent students from feeling as though their grade was in jeopardy for helping other students (Fagen 2003).

This study provided a method to analyze the potential impact of using Peer Instruction to increase student performance and understanding of genetics concepts.
through the use of ConcepTests. The opportunity for students to discuss concepts in class was used in the form of PI and was evaluated with a pre and posttest of genetics concepts.

**Definition of Terms**

For the purpose of this study, key terms are defined as followed.

1. **Alternative instruction** is defined as teacher led lectures that are interspersed with conceptual questions, called ConcepTests, designed to expose common difficulties in understanding material. The students are given 60-120 seconds to think about the question on their own and then formulate their answers. They then worked in groups of three to four, attempting to reach a common answer within a four minute time span. All students were taught by lectures, multi-media presentations, textbook usage, group laboratory assignments, and computer based laboratory quizzes outside of the alternative instruction.

2. **Biology I (BIO)** is defined as the State of Florida approved state college course BSCC 1010. This is a 16-week, 4-credit hour, 80-contact hour introductory course of biology which is composed of 3-hours of lecture and 2-hours of lab per week. The course of study covers: cell structure, function and reproduction; inheritance; development; metabolism; photosynthesis; ecology; evolution; DNA technology and related topics.
3. **ConcepTests**, as defined by Mazur (1997) are short conceptual questions designed to probe student understanding of one of the concepts discussed.

4. **Conceptual change**, as defined by Ormrod (2008) is the process of constructing knowledge from an unscientific understanding of interrelated sets of ideas to a scientifically accepted understanding of such relationships. Conceptual framework is defined as students’ understanding of targeted science concepts.

5. **Educational clickers** are defined as an interactive technology that enables instructors to pose questions to students and immediately collect and view the responses of the entire class.

6. **Genetics survey** is defined as an instrument to evaluate students’ conceptual knowledge of genetics (Fagen 2003).

7. **Interactive engagement** is defined as questioning students or challenging them to think or to do something that requires thought. Students interact with each other, with the instructor as a coach or guide, with the use of educational clickers that record their first and second answers to conceptual questions.
8. **Meaningful learning** is the defined as the process by which students connect prior knowledge to new material by building conceptual bridges (Ausbel, 1963).

9. **Metacognition** is defined as one’s knowledge and beliefs about one’s own cognitive processes and one’s resulting attempts to regulate those cognitive processes to maximize learning and memory (Ormrod 2008).

10. **Misconceptions** in science are defined as a belief that is not consistent with commonly accepted and well validated explanations of phenomena or events.

11. **Peer instruction (PI)** is a student-centered approach in which lectures are interspersed with short conceptual questions designed to challenge students to think about the material as it is being presented. Students are assigned required reading assignments before coming to class to make up for lost lecture time.

12. **Student academic characteristics** are defined as precollege preparation in the area of science; all classes in science previous to BSCC 1010 will be considered.

13. **Student attributes** are defined as the combination of students’ academic and personal characteristics. These traits are defined in Definitions 9 and 11, respectively.
14. **Student personal characteristics** are defined as a student’s age, gender, and ethnicity. The definitions of these traits are self-evident.

15. **Student retention** is defined as the number of students who enrolled in the course and the number of students that took the final exam.

16. **Targeted science concepts** for this study will be defined as targeted concepts in genetics related to genetics vocabulary.

**Research Questions and Hypotheses**

**Research questions.** The following research questions will serve as a compass for formulating the hypotheses that will be tested in this study.

1. What is the effect of Peer Instruction on state college students’ science achievement?

2. What is the effect of Peer Instruction on state college students’ retention in science courses?

3. What interaction effect exists, if any, among Peer Instruction and gender with state college students’ performance in science?

4. What interaction effect exists, if any, among Peer Instruction and students’ academic characteristics, as defined in number nine, on student performance?

5. How do student responses differ between the first time the question is posed and the final group consensus?
**Research hypothesis.** The research hypotheses that correspond to these research questions follow:

1. Instructional strategies will have an effect on state college students’ achievement. In particular:
   a. Students who participate in PI of the targeted science concepts will have higher achievement as measured by Post-Test scores than those who participate in the traditional approach to learning; PI achievement will be greater than the Traditional teaching.
   b. Students who participate in the PI courses will have a higher retention in their science course.

2. Students’ gender will have no effect on science achievement. Male achievement will equal female achievement.

3. Students’ academic characteristics (i.e., number of science courses taken before BSCC 1010) will correlate positively with on state college students’ science achievement.

4. Students correct responses will increase from the first time they answer the ConcepTest to the second submission of their answer. The number of correct responses with repetition will be higher than the number without repetition.
**Study Design**

The methodology was a quasi-experimental design. Students self-selected which courses they signed up for to accommodate their schedule. The target population of this study was all state college students in Florida taking General Biology. The accessible population was all students at Eastern Florida State College (EFSC) which is located on five different campuses throughout Brevard County in Titusville, Cocoa, Melbourne, e-Campus and Palm Bay. The target school was a state college that confers both 2-year and selected 4-year degrees. These students were in a 2-year program. The sample was derived from students registered for BSCC 1010, General Biology at the Palm Bay Campus in Palm Bay, Florida.

Classes were taught by one of three veteran instructors that have been teaching in biology for 10 plus years. Each instructor was assigned one control group in addition to their experimental group(s). All classes were taught in a classroom wired for the educational clickers. Control and treatment groups were randomly assigned. The sample size was comprised of 157 students.

The students selected to participate attended EFSC at the Palm Bay Campus during the Fall semester of 2014. Students were selected by a randomized, one-treatment-control group, pre-test/post-test, quasi-experimental design. Three
instructors were randomly assigned experimental groups and control groups. See Table 1 for schedule below.

<table>
<thead>
<tr>
<th>Instructor</th>
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**Significance of study.** Across the nation there is a general trend of poor performance in the area of sciences. Decreased performance and low attendance in first year science courses is on the rise. Students copy down lecture notes from blackboards and overhead projectors that are taken directly from the book and are subsequently copied into the student’s notebooks, giving students little incentive to attend class (Mazur, 1996). Students are then forced to memorize their notes with no real meaning attached to their learning. According to Mazur (1996) students lose their ability to concentrate after the first 15 minutes of lecture. This can lead to apathy towards science, declining achievement and result in dwindling attendance. Mazur’s work with Peer Instruction along with others in the field such as Crouch (2000), Lasry & Watkins (2008), Watkings (2009), Watkins (2013) and Miller, Lasry, Lukoff, & Schell (2014), have shown positive results in not only
increased student performance in the area of physics, but it has also shown an 
increase in student retention in science classes that use PI. Other academic areas in 
science have built upon Mazur’s work and incorporated Peer Instruction and the 
use of ConcepTests in their curriculum such as McConnell, Steer, and Owens 
(2003) in geology, however, the one area that is lacking is biology. Fagen (2003) 
set out to extend the progress of the Mazur Group in undergraduate physics to the 
biological sciences. He intended to expand the use of Peer Instruction in the area of 
genetics. What he found was lack of documentation of utilization of PI in the area 
of biology education; most predominantly the construction of a biological 
assessment tool. The area of biology proved to be anemic with most contributions 
being in the form of “how to” articles. His interest focused on identifying an 
instrument that could effectively assess student understanding of concepts in 
genetics. He developed a survey to measure students’ understanding of molecular 
and population genetics. Fagen succeeded in constructing a test for conceptual 
understanding of genetics concepts, however he bemoaned not using an interactive 
pedagogy like peer instruction to test students’ conceptual gain with the use of this 
assessment tool.

My goal was to implement Peer Instruction in a first year Biology course at 
EFSC by using the Mazur Group as a platform to expand ConcepTests into the area 
of Genetics. Fagen’s pre-test/posttest was used in this study to identify conceptual
gain in both the test groups and control groups. A few minor modifications were made by removing terms that are not used in Campbell Biology Tenth Edition and minor adjustments to the student profile indicator by using EFSC courses rather than Harvard University courses for previous coursework in science.

According to Mazur and Watkins (2013) students have more opportunities to share ideas and form bonds when instructors incorporate and structure peer discussions in introductory science classrooms. When students have more opportunities to communicate scientifically improving their conceptual understanding and metacognitive skills, they are more likely to not only attend class but also to retain knowledge. It is time the area of biology moves forward and joins the academic cavalry by implementing a diversified type of instruction in the classroom.

**Study Limitations and Delimitations**

Limitations and delimitations should be considered when reviewing the result of any educational study. Limitations are outside of the researchers control and delimitations are self-imposed by the researcher on the study to make the study manageable.
Limitations. The following limitations were considered.

1. Sampling may be a limitation in this study since the students are signing up for the courses on their own which makes random sampling impossible.

2. Student demographics may be a limitation since many of the students are from the Palm Bay area and statistically originate from a similar socioeconomic backgrounds.

3. The course curriculum is targeted for Biology I. The objectives and curriculum standards are established by the State of Florida and generalization should be similar to course curricula.

Delimitations. The following delimitations were considered.

1. Learning styles were not assessed in this study and therefore delivery of instruction could have an effect on student performance.

2. Scientific concepts to be investigated will be limited to genetics concepts. This may have different results in other areas of biology.

3. The duration of the study was limited to three weeks in an academic semester. Time could have had an effect on the results of this study, however many studies in education have the same
proposed time period or even shorter duration and still provide useful implications for classroom settings.

4. There were three instructors participating in this study. They are all considered seasoned, dynamic, and knowledgeable in their field. The purpose, procedures and scope of the study was explained to the instructors to increase treatment uniformity.

5. The achievement instrument created by Fagen (2003) was used to assess student gains in the area of genetics. The pretest was used to establish equivalency.
CHAPTER 2
Review of Related Literature

Introduction

This chapter contains three sections. The first section presents information about the theoretical foundation on which the proposed study is grounded. It contains underlying principles of cognitive development with emphasis on both cognitive development constructivism and social constructivism that are associated with Peer Instruction. The second section contains a review of past research studies in various areas of science related to Peer Instruction, and at various post-secondary settings. The chapter concludes with a summary of the related literature and a discussion of its implications to the proposed study.

Overview of Underlying Theory

Human learning is generally described from two different perspectives: behaviorism and cognitivism. Behaviorism emerged as the first major theoretical perspective in the 20th Century. There are two main behavioral learning theories, classical conditioning and instrumental conditioning (Ormrod, 2012). The roots of behaviorism are grounded in the work of Ivan Pavlov and Edward Thorndike. They focused on observable behavior instead of the non-observable mental events such as in cognitivism (Ormrod, 2012). They believed that principles of learning should apply equally to different behaviors and to a variety of animal species,
including humans. Pavlov’s work focused on classical conditioning, the idea of a stimulus and a response that is under the control of the experimenter whereas Thorndike’s research involved learning from the consequences of our behavior, instrumental conditioning. B.F. Skinner built on Thorndike’s work and used a system of rewards and reinforcements called operant conditioning (Ormrod, 2012). As in other theories of behaviorism, Skinner’s work focused on the learning of tangible, observable behaviors or responses that define learning as a change in behavior rather than a mental change (Ormrod, 2012).

With the introduction of cognitive psychology, cognitivism, in the 1960’s inadequacies of behaviorism became increasingly obvious. Behaviorists had trouble explaining how people organize and make sense of information instead of relying on rote learning. Many cognitive theorists see learning as constructing knowledge from the information received, meaning we don’t just absorb information but we try to make sense out of it. This led to a perspective of learning called constructivism. Examples of constructivist theorists are educational gurus such as Piaget and Vygotsky (Ormrod, 2012).

This study is grounded in constructivism, a branch of cognitive psychology, with emphasis on both cognitive development and sociocultural theory. In this study, students will be asked to construct their own learning of genetics concepts. They will then share their conceptual understanding with small social groups of
their peers in the classroom. It is here that their conceptual understanding of genetics will be challenged. Conceptual difficulties are a normal part of learning, and misconceptions are typical of attempts made by students to construct meanings about natural objects and events (Mintzes, Trowbridge, Arnaudin & Wandersee, 1989). PI provides opportunities for students to discuss concepts in class and learn from one another (Mazure & Watkins 2010). It is a sounding board for students to share their ideas, explain why they believe their answer is right and then re-evaluate their answers.

It is important to understand learning theories that influence and promote the kinds of learning that will facilitate students’ long-term success in science. Though no theory can be considered a fact, they are dynamic changing models that should be considered (Ormrod, 2012).

**The concept of Constructivism.** Learning is a characteristic of human beings. Behavior is instinctual with most animals. The reptilian brain, for example, has perceptual stimuli that cause reflexive action. Human behavior, however, is primarily learned. Myelination of the visual cortex, allows for mental images of objects and actions. This ability allows humans to reflect upon their thinking and their actions, to contemplate different perspectives and to think about thinking (Malerstein, 1986; Oakley, 1985; Anderson, 1992). Since the 1960’s cognitivism has been the predominant perspective in human learning research.
This approach views learning as a mental process rather than a function of stimuli and response. A student’s ability to evaluate their thinking requires metacognition. Metacognition allows students to evaluate their thinking by being active participants in their own learning process. Using metacognition about the nature of science can result in students thinking about how they perceive scientific processes and outcomes. This is a concrete way to scaffold science concepts with students. It allows them to evaluate their own thinking and determine if it aligns with commonly accepted and well validated explanations of scientific phenomena or events (Burton, 2012). First we will look at cognitive learning theory of constructivism through a wide lens and then focus on how it pertains to Peer Instruction.

Most cognitive theorists depict learning as constructing knowledge. In the constructivist model of learning, students are seen as active participants in their learning. No longer are students seen as empty vessels awaiting the information of the all-knowing, expert instructor. Instead, instructors are more of guides to learning (Bergin & Bergin, 2012). The constructivist notion is for the instructor to be a guide on the side rather than a sage on the stage. Their job is to ask more meaningful questions that can gauge the level of understanding of their students (King, 1993). This has led to different theories about constructivism. Constructivist theories can be broken down into two groups: individual
constructivism (Piagetian cognitive development constructivism) and social constructivism (Ormrod, 2012).

Piaget, a French biologist from the 1920’s, coined the term “constructivism”. His theories inspired research into cognitive development many years later. He conceived learning as a constructivist process where students create their own knowledge about the world as opposed to absorbing it. Piaget ascertained that if students create their learning they form permanent mental models but that when they simply are told facts they superficially memorize the information and it is not retained. He saw humans as naturally curious and therefore more likely to explore and want to learn more from their environment (Bergin & Bergin, 2012). From a Piagetian cognitive development constructivist view, learning takes place by interacting with the environment and introducing new schemes, specific activities or thoughts, into an existing schemata. This is done through assimilation and accommodation. If a new scheme fits with an existing scheme then assimilation occurs and there is no new learning. A cognitive equilibrium is maintained allowing a state of mental balance because the existing thought process can be used to understand current experiences and ideas. However, if a new scheme does not fit then disequilibrium occurs. Disequilibrium disturbs thinking and provides the opportunity for expanding cognition with a broader and deeper understanding. Accommodation allows old ideas to be restructured to
include new experiences and ideas. This requires more mental energy than assimilation by providing significant intellectual growth. After accommodation, the scheme goes back into the cognitive structure and then can be assimilated (Berger, 2008).

Misconception can occur when an old idea is linked to a new scheme that does not fit. Through experiences in life students make connections about the world around them that are not accurate. They assimilate knowledge by piecing together new experiences into their existing schema that is not correct. This leads to misconceptions. Misconceptions impede the assimilation of new knowledge and prevent deep understanding. In 1997, the National Research Council (NRC) presented five types of misconceptions that can interfere with learning: preconceived notions, nonscientific beliefs, conceptual misunderstandings, vernacular misconceptions and factual misconceptions. The NRC suggests that in order for teachers to break down students’ misconceptions, the teachers must first identify those misconceptions, provide a forum for students to confront them, and then help students reconstruct and internalize their knowledge, based on scientific models, (NRC, 2000).

Another prominent theorist who pioneered the sociocultural theory is Lev Vygotsky. Social interaction is pivotal in sociocultural theory also known as social constructivist theory. This theory asserts that learning results from the dynamic
interaction between the learner and the surrounding social and cultural forces. Like Piaget, Vygotsky believed that knowledge could not be directly communicated from the teacher’s head to the students’ head. According to Vygotsky (1978, p. 57), “Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first between people (interpsychological), and then inside the child (intrapsychological)”. The role of social interaction is paramount in a student’s learning. The student grows into the intellectual life of those around them. According to sociocultural theory, learning occurs when the learner acquires knowledge from a social interaction with a more competent person. This person (parent, professional, or a peer) must locate the learner’s zone of proximal development (ZPD). The ZPD consists of the knowledge or concepts that the learner is close to learning but cannot master without help (Burton & Burton, 2012; Burger, 2009). Vygotsky also believed that a complete picture of a child’s cognitive development could better be assessed by looking at both their developmental level of what they are able to do (actual development level) and their potential development level. Potential development assessment requires identifying what the child cannot do alone and then providing comprehensive instruction and practice on that task. The degree to which the child benefited from the instruction would need to be measured, but there is little quantitative data regarding such assessment techniques, (Ormond, 2012).
According to Schunk, 2011, Vygotsky’s sociocultural theory emphasizes that the facilitator of development and learning is the social environment. Apprenticeships and collaborations foster cognitive growth by stimulating developmental processes. Peer interactions transform experiences based on student knowledge and reorganize mental structures. Vygotsky saw interpersonal interactions as critical for learning to occur.

The concept of Social Cognitive Theory was introduced by Albert Bandura and is one of the most predominant theories of learning. Bandura surmised that people learn through observation. People are more likely to model behaviors of others that are perceived as similar to themselves. If they see a peer successfully complete a task they may feel like they too can achieve that task. This leads to a student’s self-efficacy or belief that they are able to accomplish the goal. A person’s perceptions and attitudes about his or her ability to do something is an important construct that can influence cognitive development (Ormrod, 2012). According to Bandura;

If actions were determined solely by external rewards and punishments, people would behave like weathervanes, constantly shifting in different directions to conform to momentary influences impinging upon them. They would act corruptly with unprincipled individuals that honorable with righteous ones and liberally with libertarians and dogmatically with authoritarians. (Bandura, 1977, p. 27).
Students control their own learning through cognitive processes in which they engage. Students who are mentally engaged will learn more effectively than those who are not. Peer interaction, class discussions, and authentic activities allow learners to think more effectively by acquiring the basic cognitive tools from classroom activities in the academic discipline. Students learn more and can remember more when they talk about their experiences or have learning tasks in which they are actively engaged (Ormond, 2012). However, information that is presented to students in a typical lecture comes so quickly that it is frequently forgotten. Cognitive scientists determined that people's short-term memory is very limited and can only process so much at once (Hanford, 2011). According to Atkinson and Shiffrin (1968, 1971), there are three basic components of memory; sensory register, short term memory (working memory), and long term memory. Sensory register is information that enters memory from the environment and is only stored for a very short time; only a few seconds to undergo preliminary cognitive processing. Short term or working memory has limited capacity and must have maintenance rehearsal in order to be retained; otherwise it is relatively short in duration. Long term memory must be consciously and actively processed. Two cognitive processes that that affect long-term memory are rehearsal and meaningful learning. Meaningful learning involves a deliberate attempt by the learner to link new information with information that is already stored. Thus, long-
term memory is facilitated by actively and consciously making associations between new information and previously stored information (Ormond, 2012). However, traditional lecture-based instruction is still the prevailing teaching method in most college science classes, even though research has shown it is not an effective way to learn. Educational research in the area of physics has shown it is impossible to retain all the information in a typical lecture. The passive absorption of massive amounts of information is not an effective way for students to learn (Hanford, 2011). Learners must be selective about what they choose to learn and study and instructors must give guidance for important information to be learned and guide their classes with appropriately paced instruction. Working memory is the key to guiding the attention and thinking processes, by condensing, organizing, and synthesizing information to facilitate long-term memory processing (Ormond, 2012).

**Peer Instruction and the relationship to constructionism.** The fundamental idea of constructivism is that learning is an active process in which learner must construct new ideas or concepts based upon their current and prior knowledge. Active engagement is an umbrella term that refers to pedagogic methods that involve students in their own learning. Peer Instruction falls under this umbrella with many other active engagement strategies. According to Prince (2004), “The core elements of active learning are student activity and engagement
in the learning process” (p. 223). Within the context of a college classroom, active learning strategies can most concisely be defined as “instructional activities involving students in doing things and thinking about what they are doing” (Bonwell & Eison, 1991, p. 1).

Chickering and Gamson emphasized in their 2001 article, “Implementing the seven principles of good practice in undergraduate education: Technology as lever,”

Learning is not a spectator sport. Students do not learn much just by sitting in class listening to teachers, memorizing pre-packaged assignments and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, apply it to their daily lives. They must make what they learn part of themselves (p. 10).

Although it is becoming more evident to many college science instructors that constructivist teaching techniques facilitate the meaningful understanding of science, many still teach in the traditional fashion. Leonard (2000) discussed the importance of constructivist learning. He stated that knowledge is actively built and the function of cognition is adaptive. By having students construct their own knowledge students are more engaged in learning and are more likely to understand concepts. Mazur noticed his students were more likely to learn concepts from their peers who just learned the material than they were from him (Hanford, 2011). This correlates with both Bandura’s Social Cognitive Theory and Vygotsky’s sociocultural theory. Constructivism allows students to be in control of their
learning and with PI students are at the helm in control of their thinking. Metacognition plays a significant role by having students think about why they have a particular understanding and reflect those thoughts with their groups while engaging in Peer Instruction (PI). In a study by Gooding & Metz (2009) it was found that student-centered learning and inquiry facilitated by the teacher allows students to have a better scientific understanding by recognizing discrepancies between their understanding and the content or concepts being studied. The use of Peer Instruction promotes metacognition by allowing students to evaluate their scientific thinking. Studies in science education research have revealed that students often fail to understand central concepts in the natural sciences despite the best efforts of good teachers (Wandersee, Mintzes, & Novak, 1994). Although learning theory has been the object of much research, many science instructors still cling to the traditional ways of teaching. Much of undergraduate biology course work consists of rote learning of vocabulary due to the immense number of terms, which often exceeds that of a beginning foreign language course, (Yager 1983). Biology courses have thousands of terms to learn and fluency in these words is imperative for students to intelligently discuss the subject and be successful in the course. Constructivist pedagogy can be used to enhance learning (Radolph, Cook, & May, 2013). There are rarely opportunities for students to practice biological terms in groups of peers in a biology classroom whereas a foreign language class
devotes significant time to such practices (Fagen 2003). This is not in sync with identified theories in both individual constructivism and social constructivism. It is important for instructors to be cognizant of students’ prior knowledge when teaching material. PI allows for instructors to be aware of students’ conceptual understanding through the use of interactive engagement in the classroom. Hake (1998) defines Interactive Engagement (IE) as a method to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors. While Traditional (T) courses make little or no use of IE methods, relying primarily on passive-student lectures, recipe labs, and algorithmic-problem exams.

Many students come to the classroom with their own erroneous ideas about science that are not true. Ausubel (1968) was quoted as saying, “The unlearning of preconceptions might very well prove to be the most determinative single factor in the acquisition and retention of subject matter” (p.336).

Misconceptions in science are widespread and not necessarily limited to students of low ability, and that even those graduating from our finest institutions experience similar problems. For example, in the documentary *A Private Universe* (Sadler, Schneps, and Woll 1987), two common misconceptions about the causes of the seasons and the phases of the moon were investigated by interviewing
Harvard University graduates, their professors, and a class of middle school students. In the documentary, Sadler et al (1987) found that both the Harvard professors and graduates along with the middle school students held false beliefs regarding these concepts. These misconceptions regardless of their age or placement in school remained deeply embedded in their schema. The students demonstrated better understanding after being retaught the concepts, although, many retained their misguided belief, by reverting back to their original misconceptions. This demonstrated that once information is learned, whether correctly or incorrectly, it is difficult to edit or delete (Gooding & Metz, 2011). It is important for instructors to be aware of student’s beliefs. When teaching in the traditional platform the teacher is at the front of the classroom and the students are left to passively observe. This does not give the students the opportunity to express what they know until it is test day. It is important to ferret out the misconceptions so that concepts can be taught and learned. PI gives students individual time to think about their beliefs and write them down. They are then allowed to share that concept with their peers and have conversations about their beliefs. This allows students to construct their own meanings and scaffold what they are learning with their peers. Constructivism refers to that process of constructing, in effect, creating a concept.
which serves as a guideline against which objects or people can be gauged. During the course of interactions with objects, people, or events the individual constructs a reality of them . . . This mental construction then guides subsequent actions with the object or events (Sigel & Cocking, 1977a, cited in Sigel, 1978, p. 334).

There is a general frustration among faculty at the college level, with the accuracy of students' understanding of science concepts. This lack of understanding of science concepts creates a major obstacle to solving science problems (Osborne & Wittrock, 1983). The need to refocus classroom efforts towards meaningful learning and conceptual understanding of scientific ideas is increasing. PI is another avenue to help students explore concepts. According to Mazur (2005) PI gives students a better understanding of fundamental concepts by discouraging bad study habits and rote learning. Students are in charge of their learning and their enthusiasm during group discussions is contagious. Through PI, students are able to think through arguments being developed and enable both the students and the instructor to assess their understanding of concepts before moving onto the next concept being learned.

**Review of Past Research Studies**

Peer Instruction was introduced in 1991 by Eric Mazur in introductory physics courses at Harvard University. His success with using PI in physics has led many to its use in a variety of other disciplines in math and science classes, however the one area that is lacking is biology.
Mazur and Crouch (2000) reported on 10 years of data using Peer Instruction in algebra and calculus based physics courses for non-majors. For their method students were required to apply core concepts presented in class through Peer Instruction and then explain the concepts to their group. The structured questioning of PI engages all students and makes them involved in their own learning, as opposed to only engaging a few highly motivated students in a traditional lecture with informal questions. The results indicated an increase in both conceptual reasoning and quantitative problem solving. A Force Concept Inventory Test was given to all students as a pretest/posttest for concept mastery at the beginning and end of the term. Scores after instruction in the calculus based physics course doubled between 1990 and 1991 with use of PI. For quantitative problem solving the Mechanics Baseline Test (MBT) was given to assess quantitative problem solving. After the first year of implementation the average score increased from 66% with traditional instruction to 72% with PI in calculus-based physics courses. The increase continued to rise in subsequent years to 79%. No MBT data was available for traditional algebra-based courses. However, the MBT scores for algebra-based physics courses increased from 62% to 66% with the use of Peer Instruction. Although there was no data to compare to traditional teaching in the algebra-based physics course, a quantitative problem was included on the final exam from a traditional algebra-based course. The results were
significant! Students taught with PI in the Spring of 2000 outperformed the students taught traditionally in the Spring of 1999. The PI students scored 7.4 out of 10 compared to 5.5 out of 10. This was a standard deviation of 2.9 and 3.7, respectively. This indicates that PI students’ quantitative problem-solving skills are comparable to or better than those who were taught with traditional instruction. Table 2.1 illustrates their results for both the FCI and MBT results in Calculus-based and Algebra-based courses (Mazur & Crouch, 2000).

<table>
<thead>
<tr>
<th>Year</th>
<th>Method</th>
<th>FCI pre</th>
<th>FCI post</th>
<th>Absolute gain (post – pre)</th>
<th>Normalized gain (g)</th>
<th>MBT</th>
<th>MBT quant. questions</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Traditional</td>
<td>70%</td>
<td>78%</td>
<td>8%</td>
<td>0.25</td>
<td>66%</td>
<td>62%</td>
<td>121</td>
</tr>
<tr>
<td>1991</td>
<td>PI</td>
<td>71%</td>
<td>83%</td>
<td>14%</td>
<td>0.49</td>
<td>72%</td>
<td>66%</td>
<td>177</td>
</tr>
<tr>
<td>1993</td>
<td>PI</td>
<td>70%</td>
<td>85%</td>
<td>15%</td>
<td>0.55</td>
<td>71%</td>
<td>68%</td>
<td>158</td>
</tr>
<tr>
<td>1994</td>
<td>PI</td>
<td>70%</td>
<td>88%</td>
<td>18%</td>
<td>0.59</td>
<td>70%</td>
<td>73%</td>
<td>216</td>
</tr>
<tr>
<td>1995</td>
<td>PI</td>
<td>67%</td>
<td>85%</td>
<td>21%</td>
<td>0.64</td>
<td>76%</td>
<td>71%</td>
<td>181</td>
</tr>
<tr>
<td>1996</td>
<td>PI</td>
<td>67%</td>
<td>89%</td>
<td>22%</td>
<td>0.68</td>
<td>74%</td>
<td>66%</td>
<td>153</td>
</tr>
<tr>
<td>1997</td>
<td>PI</td>
<td>67%</td>
<td>92%</td>
<td>25%</td>
<td>0.74</td>
<td>79%</td>
<td>73%</td>
<td>117</td>
</tr>
<tr>
<td>1998</td>
<td>PI</td>
<td>50%</td>
<td>83%</td>
<td>33%</td>
<td>0.65</td>
<td>68%</td>
<td>59%</td>
<td>266</td>
</tr>
<tr>
<td>1999</td>
<td>Traditional</td>
<td>48%</td>
<td>69%</td>
<td>21%</td>
<td>0.40</td>
<td>…</td>
<td>…</td>
<td>129</td>
</tr>
<tr>
<td>2000</td>
<td>PI</td>
<td>47%</td>
<td>80%</td>
<td>33%</td>
<td>0.63</td>
<td>66%</td>
<td>69%</td>
<td>126</td>
</tr>
</tbody>
</table>

The studies demonstrating success of PI were mainly conducted at an Ivy League school, Harvard University. However, Lasry, Mazur, and Watkins (2008) were curious to see the implications of the introducing PI at a two-year institution. They set out to see the effectiveness of this learning strategy for students with less background knowledge in the area of science. To determine the effectiveness, they compared data from the first year implementation at both learning institutions.
They looked at the Harvard courses taught with PI in Fall 1991 and the PI courses taught with PI at John Abbot College in Fall 2005. Students were randomly assigned to one of three sections: two PI sections N = 83 and one control section N = 44. The PI sections used 3-4 Concept Tests per 75 minute session, while the traditional class relied solely on lecture. All sections followed the same course outline, were taught at similar paces, and had the same laboratory experiments. Their implementation of PI is demonstrated in Figure 2.1.

They found that regardless of the institution, PI taught students demonstrated better conceptual learning and problem solving abilities than the students who had traditional instruction. In addition, they found that students with more background knowledge benefited the most from either type of instruction, however the students with less background knowledge taught with PI gained as much as students with more background knowledge when a taught traditionally.
The PI courses N = 79 obtained an average score of 68%, while the control group, N = 35 scored an average of 63%. The differences in these scores were not significant. The Harvard PI students also outperformed the control group with N = 222 with an average score of 69% and the non-PI group N = 144 scoring 63%. This was statistically significant, p < 0.001.

There was also a decrease in student attrition for both two-year and four-year institutions when taught with PI. After the first year of implementation at Harvard student retention was visited to find that out of 224 students registered for the course, all students took the final exam in the PI course. In the traditional course out of the 224 students registered for the course 26 did not take the final examination, 11.6%. After the first year student attrition increased to 5% in PI courses but dropped back down in the years to follow. Harvard PI drop rates were consistently under 5%. The same proved to be true at John Abbott College. Of the initial number of students registered in the PI course N = 83, less than 5% did not take the final exam, N = 4. In the control group N = 44, 20.5 % did not take the final exam N = 9. Figure 2.2 represents the percentage of students that dropped at both schools in both treatment and control groups.
In 2003, Fagen assessed the effectiveness of PI in a results survey. He received results from respondents from 23 countries. The United States represented with N = 320 out of the total number of respondents N = 384. The demographic breakdown of survey respondents using PI based upon country of the instructor with n=384 (Fagen, 2003).

<table>
<thead>
<tr>
<th>Country of instructor</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>320</td>
</tr>
<tr>
<td>Canada</td>
<td>20</td>
</tr>
<tr>
<td>Australia</td>
<td>11</td>
</tr>
<tr>
<td>Belgium</td>
<td>3</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>3</td>
</tr>
<tr>
<td>Spain</td>
<td>3</td>
</tr>
<tr>
<td>Sweden</td>
<td>3</td>
</tr>
<tr>
<td>Colombia</td>
<td>2</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>2</td>
</tr>
<tr>
<td>Scotland</td>
<td>2</td>
</tr>
<tr>
<td>Other (1 each)</td>
<td>12</td>
</tr>
</tbody>
</table>
Two thirds (67%) of the instructors using PI taught at universities in undergraduate courses. An additional 19% taught at four-year colleges, schools without graduate programs. Both two-year colleges and community colleges accounted for 3% each, while high schools accounted for 5%. There was 3% that were unaccounted for in this area. It was noted most of the users of PI were from universities because they are more apprised of the development and use of PI from going to conferences. The demographic breakdown of the survey respondents using PI based upon institution type is represented in Figure 2.3 (Fagen, 2003).

![Figure 2.3](image)

*Figure 2.3 Fagen breaks down of institutions currently using PI in the classroom.*

The majority of instructors taught physics. The discipline breakdown was as follows: Physics 82%, chemistry 4%, life sciences 4%, engineering 3%, mathematics 2%, astronomy 2%, and other 3%. Most of the resources for PI are geared for physics instructors, most notably Peer Instruction: A User’s Manual
(Mazur 1997) and the Project Galileo date base of ConcepTests. Figure 2.4 represents disciplines taught using PI by those responding to the survey (Fagen 2003).

![Figure 2.4](image)

*Figure 2.4  Fagen’s visual depiction of disciplines currently using PI in the classroom.*

Fagen looked into many aspects of PI in the classroom such as the most common method of collecting student responses. He found that raising hands was used by 65% of the respondents. They found it was the simplest mechanism for smaller classes. Fagen points out that there is a potential for loss of accuracy from peer pressure of choosing what the majority of the class picks to avoid the unpopular answer.

Fagen surveyed the instructor’s success with PI and based on the instructor’s responses, 60% reported that student mastery improved with PI. An additional 20% claim that student mastery improves somewhat, while 19% found there was no difference from traditional lectures.
The instrument most commonly used was the Force Concept Inventory (FCI) to gauge student gains (81%) which is not surprising since the majority of PI instructors teach physics.

Instructor satisfaction was also taken into account in Fagen (2003) survey. He found that a vast majority of respondents reported a positive experience (93%) with less than 1% reporting a negative experience (an additional 5% had a mixed reaction). An instructor of Chemistry wrote: “I’m convinced more is learned and retained. Student attendance is way up, attrition way down (almost zero), and attitude far more positive” (Fagen, 2003). While a mathematics professor said students were more successful in the Peer Instruction class. They did more work and complained less and the average grade was higher than the traditional class.” (Fagen, 2003).

The majority of research involving inquiry learning has been at the university level in the area of physics, however, Knight and Wood (2005) focused their attention on biology students at the University of Colorado. The study was carried out to determine student learning gains in a traditionally taught, upper-division lecture biology course. The classes were taught by two instructors using the same syllabus and lab activities in the Fall of 2003 and the Spring terms of 2004 and 2005. They set out to determine learning gains by partially changing to an interactively taught format. In the Fall of 2003 they used a strictly traditional format and used that term as their control group. In the Spring of 2004 they gently staggered the amount of
interactive teaching by adding interactive techniques gradually. Students were put into groups at the beginning of the term and those groups worked together in lab as well. Students were graded on group work and group participation (Knight & Wood, 2005). In the Spring of 2005 they repeated the study to assess reproducibility. Though the classes were still 60 to 70 percent lecture, they used frequent in-class questions (ICQ) that were based off of Mazur’s ConceptTests in physics (1996). The learning demands put responsibility on the students to learn outside the classroom with homework problems and to solve in-class problems cooperatively in groups during class time, along with other techniques such as concept maps and journal articles. Their findings paralleled the results found in other disciplines, by replacing some of the lecturing with interactive engagement and cooperative learning (Knight & Wood, 2005). Students were given a pretest at the beginning of the term that they received points for completing, not for correctness of answers. At the end of the term the post-test was given as 15 questions embedded in their final exam. This study was testing a variety of cooperative learning techniques on biology students which also included Just in Time Teaching (JITT) methods, homework and group work as part of the experiment. Just in Time Teaching Methods are Course points were changed to include homework, group work, and in-class participation. The number of grades of “A” decreased in the interactive course due to the removal of the curve that was given in the Fall 2003 traditionally taught class. This was removed to encourage students
to work in groups and not feel they were hurting their grade by helping their peers. However the grades of “B” achieved were 51% in the interactive course while the traditional course had 37%. Performance on the pre-test was not that significant between traditionally taught students and the interactive classroom students. The post-test however had significantly higher scores in the interactive course by 9 percentage points (p ¼ .001, two tailed t-test). Normalized learning gains from the pretest and posttest in the Fall 2003 and Spring 2004 courses showed a significance of 16% difference (p ¼ .001) in average learning gains, corresponding to a 33% improvement in performance by students in the more interactive S’04 course. Learning gains of greater than 60% were achieved by substantially more students in the interactive class (43/70) than in the traditional class (19/72). Normalized learning gain was defined as the actual gain divided by the possible gain, expressed as a percentage \[100 \times \frac{\text{posttest} - \text{pretest}}{100 - \text{pretest}}\] (Fagan et al., 2002).

In a study by Lasry (2008), the effect of PI and the medium used in which to present ConcepTests to students was examined. First-year students in an algebra-based mechanics course at a two-year Canadian community college were randomly assigned to one of two sections taught by Lasry. The first section consisted of PI with clickers \(n = 41\) while the other followed PI with flashcards \(n = 42\) to respond to in-class ConcepTests. Both sections followed the same course structure and content
(using 3-4 ConceptTests with peer discussion in each class), and had the same laboratory component.

Force Concept Inventory was given as a pre-test posttest at the beginning and end of the term to establish if clickers increased student learning using PI. In addition students’ final exam scores were in each group were compared. As shown in Table 2.3, student scores were not significantly different in PI courses using clickers.

**Table 2.3 The effect of clickers: difference in learning data between flashcard and clicker groups, by Lasry.**

<table>
<thead>
<tr>
<th></th>
<th>Pre-FCI /30</th>
<th>Post-FCI /30</th>
<th>g</th>
<th>Exam (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clickers (n=35)</td>
<td>11.9</td>
<td>19.9</td>
<td>0.486</td>
<td>69.8</td>
</tr>
<tr>
<td>Flashcards (n=34)</td>
<td>13.6</td>
<td>21.3</td>
<td>0.520</td>
<td>71.6</td>
</tr>
<tr>
<td>t-test (2-tailed p)</td>
<td>0.209</td>
<td>0.351</td>
<td>0.745</td>
<td>0.630</td>
</tr>
</tbody>
</table>

This indicates that the use of clickers in the given study did not add to the conceptual learning of students or to the final exam scores. The effectiveness of PI as an instructional approach is independent of the use of technology such as clickers.

McConnell et al. (2003) described a variety of interactive engagement learning strategies for non-science majors to develop higher order thinking skills in earth science courses at the University of Akron. They used Blooms Taxonomy as a guide to identify critical thinking skills and link them to assessment methods used as IE in the classroom. Among the IE methods they looked at ConceptTests, Venn
diagrams, Image analysis, Concept maps, open-ended questions and evaluation rubrics. In Table 2.4 they compared six formative assessment methods and Blooms Taxonomy. These IE techniques were incorporated into the classes they deemed Inquiry-based learning. The classes without Inquiry-based learning were the Traditional classes. Characteristics of both are represented in Table 2.5.

### Table 2.4 Formative assessment methods and Bloom's taxonomy, McDonnell et.al. (2003)

<table>
<thead>
<tr>
<th>Bloom's Taxonomy</th>
<th>Learning Skill</th>
<th>Concept-test</th>
<th>Venn Diagram</th>
<th>Image Analysis</th>
<th>Concept Map</th>
<th>Open-ended Question</th>
<th>Evaluation Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>memorization and recall</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Comprehension</td>
<td>understanding</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Application</td>
<td>using knowledge</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Analysis</td>
<td>taking apart information</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Synthesis</td>
<td>reorganizing information</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Evaluation</td>
<td>making judgments</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

### Table 2.5 McDonnell’s Traditional vs. IBL Characteristics

<table>
<thead>
<tr>
<th>Traditional</th>
<th>Inquiry-based Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive students</td>
<td>Active students</td>
</tr>
<tr>
<td>Quiet</td>
<td>Noisy</td>
</tr>
<tr>
<td>Instructor-focused</td>
<td>Student-focused</td>
</tr>
<tr>
<td>Information from instructor to student</td>
<td>Information from student to student</td>
</tr>
<tr>
<td>Students as individuals</td>
<td>Student collaboration</td>
</tr>
<tr>
<td>Competitive learning environment</td>
<td>Supportive learning environment</td>
</tr>
<tr>
<td>Limited assessment opportunities</td>
<td>Multiple assessment opportunities</td>
</tr>
<tr>
<td>Rigid setting (lack of mobility)</td>
<td>Mobile environment for instructor and student</td>
</tr>
</tbody>
</table>
Results were interpreted from both groups in the form of student evaluations, student interviews, student retention, and exam scores. The majority of students viewed the active learning methods positively, 79 percent. Student retention was measured by the number of students present for the first and last exam. Results showed 14% higher retention in the IBL courses. The exam scores were only slightly higher in the IBL courses, however, there were twelve short-answer interpretation questions that involved Blooms higher level questions in the form of analysis, synthesis, or evaluation. The average score on the on these questions was 7% greater in the IBL sections (McDonnell et al, 2003).

For decades there have been multiple studies to investigate the differences in sex and science achievement, (Jones, Howe, & Rua, 2000). In a study by Halpern et al (2007), it was noted that females are underrepresented in science and mathematical academic positions at research universities. Though gender gaps have been evident in the areas of math and science predominately, according to Robinson et al (2011), many studies find the correlation in attitudes towards science, technology, engineering, and mathematics (STEM).

In a 12 year study by Lorah and Ndum (2013) trends in first year college student gaps in achievement, as made evident in prior studies, were investigated from the perspective of different subgroups. The portion of this study that was relevant to the research question addressed in this study was first year biology.
students’ achievement in accordance to gender. Successful completion of the class was defined as a B or better and a C or better. The overall study showed an achievement gap between males and females. The females were outperforming the males in first year college courses. According to their results, the success for the B criteria in Biology was 32% less for males. The success for C criteria were 30% lower in Biology, respective to females. However, the achievement gap narrowed between the years of 1998 and 2009.

**Summary and Study Implications**

Educational research findings suggest that instructors can nurture the growth of cognitive abilities and promote science literacy in the classroom by incorporating the Constructivist approach to learning in the classroom through active learning strategies (McConnell, Steer & Owens, 2003). Hake 2002 defines Interactive Engagement (IE) methods as “those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors.” In contrast he defines the Traditional (T) framework of teaching as, “Courses as those reported by instructors to make little or no use of IE methods, relying primarily on passive-student lectures, recipe labs, and algorithmic-problem exams. According to Starting Point Teaching Entry Level Geoscience, active learning occurs when instructors build learner participation into
classes where the students interact with each other, and the instructor is more of a coach or a guide. The majority of quantitative research in science education regarding the effectiveness of IE in a learning environment comes from the physics community and the results are highlighted below from http://serc.carleton.edu/introgeo/models/IntEng.html.

- Peer Instruction/Concept Tests (Eric Mazur, Harvard University)
- Interactive Demos (R. Thornton, Tufts; D. Sokoloff, U. of Oregon)
- Cooperative Problem Solving (Ken and Pat Heller, University of Minnesota)
- IE Modeling activities (Hestenes, Arizona State);
- IE Models, simulations, and animations (Christian and Belloni, Davidson College);
- Interactive Lectures and Just in Time Teaching, (G. Novak, Purdue; E Patterson, AF Academy; Andrew Gavin, Purdue; and Wolfgang Christian, Davidson College);

The constructivist model of student thinking and learning has evolved using the research to develop a number of curricula and infuse them into the classroom through the use of interactive engagement strategies (Reddish, 1996). In Figure 2.5 the relationship between these strategies are given to visually place the relationship of these techniques with PI.
The successful implementation of IE learning, requires a student-centered approach. Small groups of students is more amenable to IE, however, individual response systems along with peer instruction techniques create a quality IE environment for larger classes (Redish, 2003).

The cerebral cortex is the part the brain most closely associated with cognitive function. According to Zull (2004) engaging the four areas of the cortex will enhance learning by allowing more neurons to fire causing more neural networks to change. Biochemical pathways in the brain stimulate neurons to grow and branch out as new information is learned, changing the shape of the brain. These neurons not only branch out but will eventually connect forming active walls
of neurons sending out and receiving information. When instructors use a variety of teaching techniques to reach their students, the students are using more of their brain causing more neurons to fire. Peer Instruction allows students to discuss conceptual material with a person that has a similar network of neurons. Zull argued that the knowledge of an instructor is different than their students’ and the students formulate their ideas differently due to the physical arrangement of their brain. Students’ networks are better fitted with their peers when it comes to learning and understanding (Zull, 2004). Theorists such as Vygotsky and Piaget understood the importance of peers and learning.

Zull emphasized building upon student errors because the errors became the foundation upon where new learning could grow. He saw them as gaps in the students’ network that needed to be filled (2004). It was a place for accommodations to be made before the new material was assimilated and the brain reached equilibrium (Berger, 2008). Student misconceptions in science are not a new phenomenon; in fact, they have been the object of unprecedented research in science learning. Learning science is difficult because it is based on higher order thinking and abstract processes that can involve mathematical skills, however, the major impediment rests in students’ misconceptions of science concepts. Students often come into the classroom believing in their extemporaneous conceptions that are in conflict with accepted scientific knowledge, which in turn interferes with the
learning of science. Misconceptions in science are frequent, and are particularly difficult to eradicate, which makes the persistence of these misconceptions a fundamental obstacle to science learning (Mason, Potvin, Riopel, Foisey, & Lafortune, 2011). Peer Instruction (PI) allows instant feedback to the instructor through the use of ConcepTests, which reveals the students’ understanding of concepts as they are introduced to them in class (Mazur, 1997). This allows the instructor to gauge how much time to spend on a certain topic based on the results of the ConcepTests. If the majority of the students choose the correct answer to the ConcepTest, the lecture will proceed to the next topic. However, if after the discussion the percentage of correct answers is below 90%, the instructor slows down and goes into more detail on the subject. Students will then be reassessed with another ConcepTest (Crouch, Watkins, Fagen, and Mazur, 2002). In order for this to be successful it is important to choose questions that require higher order thinking about concepts and not use “plug and chug” questions that students can simply recall from something they memorized or read. Students should be challenged with questions that are of appropriate difficulty level so they can reason the answer with their existing knowledge (Mazure and Watkins, 2009).

Through the use of educational clickers, instructors have immediate feedback on student answers to conceptual questions. Studies have not shown an increase in student success in using educational clickers but they do reduce class
time of tallying the results of flashcards or hand number of hands raised. Many instructors who have adopted the PI approach have adopted educational clickers for the ease of archiving student results on ConcepTests. The general idea behind using educational clickers in the classroom is in Figure 2.6 (Lasry, 2008).

![Figure 2.6 How to incorporate PI with clickers. From Lasry 2008.](image)

Interactive engagement in the classroom helps instructors to see conceptual misunderstandings instantly by reflecting the number of correct and incorrect answers. Instructors can readdress the conceptual questions by letting the class discuss their perceptions to their group depending on the needs of the class. Through conversations with their peers, students are able to make accommodations to their existing schemes so real learning occurs. After a revote, through the use of the clickers, the instructor can decide whether to continue to the next topic or to revisit the concept.
From *A Private Universe*: Every time we communicate, new concepts compete with preconceived ideas. All students hold these ideas, but are unaware of their private theories. We must make them aware. Only then can we enable them to learn, and free them from their private universe (Sadler, Schneps, & Woll, 1987).
CHAPTER 3

Methodology

Research Methodology

The methodology was a quasi-experimental design. Students were selected by a one-treatment-control group, pretest/posttest, quasi-experimental design. The students who were selected to participate attended Eastern Florida State College at the Palm Bay Campus during the 2014 Fall semester. Treatment and control groups were selected randomly. Treatment groups were taught with Peer Instruction while the control groups were taught with a traditional teaching approach. Pilot studies were performed in both the Spring and Summer 2014 semesters, to serve as baseline data to compare with study results.

To demonstrate group equivalency a pre-test was given at the beginning of the term to identify that all groups are equally matched on the study’s dependent variables. The results of the assessment were statistically examined to determine similarities in age, gender, ethnicity, and science background. The instructors in this study all use the same book, Campbell Biology 2010, the same weekly labs, and the same lab manual.

Instrumentation

Two instruments were used to measure science achievement in this study; ConcepTests as introduced by the Mazur Group and genetics survey by Fagen
The ConcepTests were given to the treatment groups throughout their unit in Genetics. The genetics survey was given at the beginning of the semester, during Week 2, to confirm group equivalence. It was also administered at the end of Week 12 as a post-assessment. A brief description of the instruments is as follows:

**ConcepTests.** The ConcepTests are based on the Mazur Group’s Project Galileo. There are an abundance of ConcepTests for other science disciplines, however, there were limited ConcepTest questions for biology in the area of genetics on the site. Content validity was assessed by a team of biology professors at Eastern Florida State College that have been teaching in the field for 20 plus years. Additional questions for ConcepTests came from Campbell 10th Edition Course Outline Notes. Below are examples of ConcepTest questions that were used.

1. How does the genetic material in a **skin** cell compare to the genetic material in a **liver** cell?
   a. The genetic material is identical in both cells
   b. The genetic material is mostly similar, but differs somewhat
   c. Different amount of genetic material but can't tell how
   d. Different content of genetic matter

**Answer:** Each cell in your body (with the exception of sperm and eggs) should have the **identical** genetic material. (Fagen, 2000).
2. In a cell with 14 chromosomes, a cell that results from Meiosis I should contain how many chromosomes.

   a) 14                     c) 7
   b) 10                     d) 28

General Concept

<table>
<thead>
<tr>
<th></th>
<th>Meiosis I</th>
<th>Meiosis II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell number:</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Chromosome number:</td>
<td>2n</td>
<td>n</td>
</tr>
</tbody>
</table>

ConcepTests are given by interspersing presentation of course material with related conceptual questions which probes students’ understanding of central concepts being presented. When the question is first asked, students are given one or two minutes to formulate their individual responses. Afterwards students have time to discuss their answers with their group and convince them of their correctness. The instructor moves around to listen to these discussions to hear possible misconceptions that may exist in the classroom. The instructor ends the group discussions by calling for a final polling of individual answers. These answers may or may have not changed due to group conversations. ConcepTests provide students with opportunities for conceptual change by allowing students time to reconstruct their ideas about a given concept.
Each ConcepTest has the following general format:

1. Question posed - Up to 1 minute

2. Students given time to think – Up to 1-2 minutes

3. Students record/report individual answers

4. Neighboring students discuss their answers – Up to 2-4 minutes

5. Students record/report revised answers

6. Feedback to teacher: Tally of answers

7. Explanation of correct answer 2+ minutes

**Genetics survey.** The genetics survey pretest/posttest is composed of questions based on Fagen (2003). This tool evaluates student knowledge, which addresses a wide spectrum of data pertaining to the student. The survey begins with low level questions that test the student’s ability to recognize genetics terminology and rate their familiarity in the context of biology. It builds on familiarity of terms by having students describe biological significance and ultimately complete multiple choice and short answer questions that addressed student understanding of genetics concepts. This assessment gathers information on students’ understanding of genetics concepts that build from their use in a
biological context. In addition, background information of students, such as demographics, and science course experience is embedded in the survey. A pilot test was performed during the Spring 2014 semester. The original survey was modified to meet the needs of EFSC students. Not all questions on the original survey were relevant to EFSC. For example, in the area of terminology, some questions were removed that are not found in the Campbell Biology 2010 textbook along with minor adjustments to the student profile indicator by using EFSC courses rather than Harvard Universities’ courses for previous coursework in science. Some examples of the questions used in the survey instrument are as follows:

1. What does it mean, at a molecular level, to say that a trait is dominant?

2. You are asked to serve on a jury considering a paternity case. A single mother of a baby is trying to get the father to pay his share of child support. The man she has identified as the baby's father denies the charge. They agree to perform a genetic test; they obtain DNA samples from the child, mother, and accused father and look at the length of DNA fragments resulting from a restriction enzyme digest in a certain region of the human genome. The child shares some of the DNA fragments with the mother but also has several fragments not shown in the mother's sample.
(a) If the man’s sample contains fragments which match up exactly with those of the mother, what, if anything, could you conclude about the accused man’s paternity?

(b) If the man's sample contains fragments which match up with those of the child *not* present in the mother, what, if anything, would you conclude about the accused man's paternity?

**Instructional Model**

Two different instructional models were used in this study. Peer Instruction (PI) and traditional teaching methods (control). The PI model incorporated teacher led lectures that were interspersed with conceptual questions, called ConcepTests, designed to expose common difficulties in understanding material. The students were given 60-120 seconds to think about the question on their own and then formulate their answer. They then worked in groups of three to four, attempting to reach a common answer within a 60-120 seconds time span.

All students, PI and control, were taught by lectures, multi-media presentations, textbook usage, group laboratory assignments, and computer based laboratory quizzes outside of the alternative instruction, PI.

**Course description.** Biology I (BIO) is a State of Florida approved state college course BSCC 1010. This is a 16-week, 4-credit hour, 80-contact hour introductory course of biology which is composed of 3-hours of lecture and 2-hours
of lab per week. The course of study covers: cell structure, function and reproduction; inheritance; development; metabolism; photosynthesis; ecology; evolution; DNA technology and related topics.

**Procedures**

Students’ conceptual framework on targeted science concepts were assessed as intact groups from General Biology 1, BSCC 1010, a first year biology course. During the treatment, alternative instruction in the form of peer instruction was used to integrate targeted genetics concepts into students’ schema. Conceptual change was assessed both individually and as separate groups by use of ConcepTests based on Peer Instruction: A User’s Manual [Mazur 1997]. The answers were scored using a computerized voting system by means of educational clickers to score individual and group responses. These scores were evaluated to determine if there was conceptual change in the answers from the first “individual” response to the second “individual response” after discussing their theories with a pre-determined group. In addition, a pre and posttest was administered in the form of a genetics survey. It included a survey designed by Fagen (2003) that addresses concepts covered in the course in the area of molecular and population genetics. It also addressed background information on students in regards to student demographics and science course experience, on the pretest, while the posttest concentrates on their experience throughout the semester.
Population and Sample

Population. The target population of this study is all State College students in Florida enrolled in General Biology 1. The accessible population is all students at Eastern Florida State College, which is located on five campuses between the northernmost campus in Titusville and the southernmost campus in Palm Bay. The samples were selected from students registered for Biology 1 on the Palm Bay Campus. Eastern Florida State College confers both 2 and 4 year degrees.

Brevard County is located on the east coast of Florida nestled along the Atlantic Ocean. Brevard is unique because in addition to being a coastal community it is home to 72 miles of the Indian River Lagoon, which is the most diverse estuary in North America.

According the 2010 US Census, Brevard is the 9th most populated county in the state of Florida with 543,376 residents. Brevard County is also referred to as the Space Coast due to the location of John F Kennedy Space Center. The educational background of residents 25 years old or older reported 26.4% have a bachelor’s degree or higher while 90.6% reported having high school diploma or higher. Other demographic information of Brevard County, race and ethnicity was determined to be 84.2 % White, 10.5% Black, 0.5 % American Indian/Alaskan Native, 2.3% Asian, 0.1 % Native Hawaiian/Other Pacific Islander, 2.4% two or more races. The U.S. Census Bureau defines Hispanic as a culture and not a race.
It is estimated that the population in 2012 was 8.8% Hispanic or Latino. Of the Hispanic population 12.1% are Mexican, 37.8% are Puerto Rican, 8.8% are Cuban, and the remaining 42.2% are qualified as other Hispanics/or Latino. The median home price in Brevard County went from $248,700 in 2005 to $125,200 in 2007. The 2007-2011 median household income was $50,068. As part of this study, student demographic information will include SES, ethnicity, and student academic characteristics, precollege preparation in the area of science. All science classes previous to BSCC 1010 were considered. The major characteristics of this sample are described in the Table 5.

Sample. A sample size of 157 Eastern Florida State College students participated in this study. The students selected were enrolled in BSCC 1010, General Biology 1, during the 2014 Fall semester. The sample was taken from the Palm Bay Campus, the southernmost campus in Brevard County. A separate control group was selected for each instructor. Palm Bay is the largest municipality by population in Brevard County. A summary of student composition at EFSC is listed below for each campus.
Table 3.1  *Summary of Eastern Florida State College’s Students’ Personal Characteristics*

<table>
<thead>
<tr>
<th>Campus</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>M</th>
<th>F</th>
<th>A</th>
<th>B</th>
<th>H</th>
<th>W</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB</td>
<td>3565</td>
<td>15</td>
<td>71</td>
<td>26.5</td>
<td>1639</td>
<td>1926</td>
<td>71</td>
<td>695</td>
<td>562</td>
<td>2072</td>
<td>164</td>
</tr>
<tr>
<td>Cocoa</td>
<td>4724</td>
<td>14</td>
<td>73</td>
<td>27.9</td>
<td>2035</td>
<td>2692</td>
<td>119</td>
<td>523</td>
<td>375</td>
<td>3503</td>
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<tr>
<td>Melb</td>
<td>5218</td>
<td>14</td>
<td>71</td>
<td>25.8</td>
<td>2624</td>
<td>2594</td>
<td>147</td>
<td>384</td>
<td>548</td>
<td>3914</td>
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<tr>
<td>Titus</td>
<td>1695</td>
<td>16</td>
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<td>26.9</td>
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<td>946</td>
<td>25</td>
<td>206</td>
<td>128</td>
<td>1264</td>
<td>72</td>
</tr>
<tr>
<td>Overall</td>
<td>15206</td>
<td>26.8</td>
<td>7047</td>
<td>8158</td>
<td>562</td>
<td>1613</td>
<td>362</td>
<td>1808</td>
<td>1613</td>
<td>10753</td>
<td>576</td>
</tr>
</tbody>
</table>

Table 3.2  *Student demographics for BSCC 1010 at each of the EFSC campuses.*

<table>
<thead>
<tr>
<th>Campus</th>
<th>N</th>
<th>M</th>
<th>F</th>
<th>A</th>
<th>B</th>
<th>H</th>
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<td>PB</td>
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<td>7</td>
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<td>238</td>
<td>17</td>
</tr>
<tr>
<td>Titus</td>
<td>126</td>
<td>50</td>
<td>76</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>109</td>
<td>5</td>
</tr>
<tr>
<td>Overall</td>
<td>913</td>
<td>370</td>
<td>543</td>
<td>18</td>
<td>95</td>
<td>90</td>
<td>665</td>
<td>45</td>
</tr>
</tbody>
</table>

**Power analysis.** An A Priori ANCOVA: Fixed effects, main effects and interactions power analysis was conducted on GPower giving a medium effect size of .25 and an actual Power of 0.8014112 for a sample size of 128. A sample size of 157 students was used, based on the analysis, to allow for possible mortality. By using a large sample size, these secondary independent variables should not interfere with the original independent variable, Peer Instruction. See Table 3.3 for Power Analysis on all variables and their corresponding statistical analysis methods.
Table 3.3

*Power Analysis and Estimated Sample Sizes (N)*

<table>
<thead>
<tr>
<th>Variables&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Test Type</th>
<th>$\alpha$</th>
<th>Power</th>
<th>ES</th>
<th>Estimated N</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ 1</td>
<td>ANCOVA</td>
<td>0.05</td>
<td>0.8</td>
<td>0.25</td>
<td>128</td>
</tr>
<tr>
<td>RQ 2</td>
<td>t Test</td>
<td>0.05</td>
<td>0.8</td>
<td>0.25</td>
<td>116</td>
</tr>
<tr>
<td>RQ 3</td>
<td>ANCOVA</td>
<td>0.05</td>
<td>0.8</td>
<td>0.25</td>
<td>128</td>
</tr>
<tr>
<td>RQ 4</td>
<td>ANCOVA</td>
<td>0.05</td>
<td>0.8</td>
<td>0.25</td>
<td>128</td>
</tr>
<tr>
<td>RQ 5</td>
<td>t Test</td>
<td>0.05</td>
<td>0.8</td>
<td>0.5</td>
<td>27</td>
</tr>
</tbody>
</table>

*Note.* Each RQ is considering the specified variable for each research question posed in Chapter 1.

**Data Analysis**

Possible intervening or confounding variables include gender, science experience, ethnicity, and socioeconomic status (SES). Part of the genetics survey has a section on student demographics and was used as a method for controlling these independent variables. This section provided information to the researcher on students’ science experience, gender, ethnicity and their SES. The participants were then be matched on these relevant factors to provide partial control over the selection threat.

The pretest and posttest was an instrument created by Fagen (2003) to assess students’ background and familiarity with genetics terminology (Appendix A). Eighty-seven terms from the glossary of the course text — *Genetics: Analysis of Genes and Genomes* [Hartl and Jones 2001] — were used on the original instrument, however, Campbell 2010 did not have all of those terms so the number was reduced.
to fifty terms EFSC students would have access to in their textbook. Student familiarity with the terminology was based on a 1-5 scale:

1 = Very Poor
2 = Poor
3 = Average
4 = Good
5 = Excellent

Two made-up terms, “clastron” and “spooling”, with no known meanings in the biological sciences were included to serve as a control. A student designating a familiarity of 3 with clastron or spooling might suggest that he or she was less likely to suggest a low familiarity at all (Fagen, 2003).

In addition, students were asked to define 12 of the terms, including the two fictitious terms, to assess the how well the students actually understood the terms. These fill in the blank answers were also graded on a 1-5 scale. Any items left blank were given a score of 1, based on Fagen (2003).

The survey also contained several questions designed to address concepts covered in the course in the areas of genetics as well as background information on the students. In particular, there was one multiple-choice question designed to address a common misconception about the nature of genetic material, one free-
response question, and one two-part data interpretation question (the complete
survey is available in Appendix A).

The pre-test version of the survey differed from the posttest version. On the
pretest, students were asked to provide information about their previous experience
and preparation in the sciences, such as their high school and college science
coursework, student demographics and their career aspirations. The demographic
questions served to assess the respondent’s gender and years of science experience.
Career goals also served as an indicator of the students’ interest in science. On the
post-test, students were asked to evaluate the course and their experience during the
term. Students were asked to put their name on the surveys so they could be
matched pretest/posttest at the end of the term. Student understanding of genetics
terminology was assessed individually (Table 9).

<p>| Table 3.4 Individual Student responses for each term for both the pre and posttest |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Student</th>
<th>allel</th>
<th>amino acid</th>
<th>anaphase</th>
<th>anticodon</th>
<th>autosome</th>
<th>bacterio</th>
<th>centrome</th>
<th>chiasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Student responses in the pretest were compared with student responses in
the posttest. Students’ initial familiarity with a term (f pre) was correlated with his
or her familiarity at the end of the semester (f post). An independent-measures
research t Test was used to analyze if there is a significant mean difference between the traditional and experimental groups using PI. An ANCOVA was used to evaluate the mean difference between scores obtained from the treatment and control groups. Descriptive statistics involving student background information and fill in the blank answers are provided in Chapter 4.

Table 3.5

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Data Analysis</th>
<th>IV</th>
<th>DV</th>
</tr>
</thead>
<tbody>
<tr>
<td>HO1a</td>
<td>ANCOVA</td>
<td>PI</td>
<td>ACH</td>
</tr>
<tr>
<td>HO1b</td>
<td>Independent Measures t Test</td>
<td>PI</td>
<td>Ret</td>
</tr>
<tr>
<td>HO4</td>
<td>Dependent Measures t Test</td>
<td>Iclick</td>
<td>Pclick</td>
</tr>
</tbody>
</table>

Note. IV = Independent variable, DV = Dependent variable. PI = Peer Instruction. ACH = Achievement, R = Retention. Iclick = Initial click, Pclick = Post click.

For HO3 and HO4 interaction effect must be taken into account. Interaction effect between gender and PI was examined. Interaction effect between PI and academic characteristics was examined pertaining to achievement with PI and traditional teaching methods. To further investigate the research factors were examined with the covariate to distinguish the interaction effect between the dependent variable and the independent variables. The independent variables included the covariate (the pretest) and research factors (gender, academic
characteristics, and pre/post ConcepTest answers). The posttest was the dependent variable.

The independent variables were organized into three functional sets: Set A (covariate), Set B (research factors) and Set C (interaction), which is the product of the covariate and research factor (Set A X Set B). The posttest is the dependent measure and will comprise Set D, the dependent variable set. The variables and set memberships are summarized in Table 3.5.

### Table 3.6
Summary and Description of Independent and Dependent Variables

<table>
<thead>
<tr>
<th>Sets/Variables</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set A = Covariate</td>
<td>Set A is a single-variable that represents the Covariate, which refers to the pretest score on the Genetics Survey given Week 2 of the Fall 2014 semester.</td>
</tr>
<tr>
<td>X₁ = Pretests</td>
<td></td>
</tr>
<tr>
<td>Set B = Research Factors</td>
<td>Set B is a multivariable set of research factors: gender (X₂) is dummy-coded with males as the reference group; Academic Characteristics (X₃) refers to the number of prior science coursework. This was dummy-coded by number of prior courses, with zero as the reference group.</td>
</tr>
<tr>
<td>X₂ = Gender</td>
<td></td>
</tr>
<tr>
<td>X₃ = Academic Characteristics</td>
<td></td>
</tr>
<tr>
<td>Set C = Interaction Effect</td>
<td>Set C is the product of the Covariate (pretests) and Demographics Set A X Set B = Set C.</td>
</tr>
<tr>
<td>Set D = Dependent variable</td>
<td>Set D is single-variable set that represents the dependent measure, namely, student achievement, which consists of students’ Posttest score on the Genetics Survey by Fagen 2003.</td>
</tr>
<tr>
<td>Y = Student achievement</td>
<td></td>
</tr>
</tbody>
</table>

*Note. The set entry order for the hierarchical regression analysis that corresponds to the correlation component of the study is B–A–C.*
**Study Implementation**

**Human subject research issues.** Attention to human subject research issues were addressed by submitting an application to FIT and EFSC for an IRB. Both institutions require an IRB to be approved before student information can be obtained. They were provided to the appropriate departments at both institutions and were approved. This research was conducted in an educational setting to assess instructional strategy effectiveness. There were no known or foreseeable risks to students in this study. A copy of both FIT and EFSC’s approval can be found in the appendix portion of this dissertation.

**Implementation issues.** Prior to the study in the Fall 2014 term instructors participating in the study were brought together to discuss PI and its implemented in the classroom. Topics discussed included: (1) an introduction to PI; (2) a visual diagram of ConcepTests administration with respect to time and placement in the lesson; (3) copies of the pre- and post-assessments, and the details of their administration; (4) an introduction to the educational clickers; (5) how to access the educational clickers on their class computer; (6) the importance of each student retaining the same clicker for the extent of the study; (7) potential threats to the internal and external validity of the study; and (8) any other issues related to the study. All participating teachers were provided with an introduction to the study, copies of the objectives and instruments, and copies of the ConcepTests.
During the second week of classes, consent forms and pre-tests were administered to the students and returned back to the principle investigator. Another informational meeting with the instructors participating in the study took place to demonstrate how to use the educational clickers and software. To practice using active engagement before the actual study, questions were made for a photosynthesis and cellular respiration review so students could practice with the clickers one week before implementation of the study. This allowed for trial and error with regards to both the faculty and students understanding with the clicker manipulatives and how to both teach and participate in a PI environment. All ConcepTests were entered into the Educational Clicker program along with pre-study questions to help with adjustment to the study.

A pilot test was implemented during the Spring 2014 term. This was done to flush out any possible challenges before the full implementation during the Fall 2014 term. Due to campus-wide overall low enrollment and to plan for potential issues, the pilot was truncated to only have two instructors teach the treatment groups; instructor A and instructor B (the primary investigator). The other instructors, instructors C and D were used as the control groups and gave out pre-tests to practice for the execution of the actual study in the fall. During the pilot test potential issues were anticipated on a smaller scale.
Table 3.7.  *Pilot Test instructors and their corresponding treatment or control groups.*

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Treatment</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A and B</td>
<td>C and D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>F and G</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>H</td>
</tr>
</tbody>
</table>

During the Summer 2014 term, an alternative computer program was used to determine the effectiveness of employing ConcepTests to students. The platform used was Learning Catalytics, a Pearson product that accompanies the Mastering Biology website that can be used as a companion site for biology instructors and students. Learning Catalytics was founded in late 2011, by Eric Mazur, the Balkanski Professor of Physics and Applied Physics at Harvard University. Learning Catalytics uses data analytics to improve learning in the classroom, by allowing teachers to ask students open-ended critical thinking questions and receive timely feedback (Mazur Group, 2014). Educational clickers are not needed because they simply sign into their Mastering Biology account with their phones, tablets or lap top devices. Students can use their touch screen to draw diagrams, graphs or shade areas that correspond to the question. This gives more variety to the types of questions that can be asked in addition to multiple choice, fill in the blank and T/F questions. In addition, Learning Catalytics allows teachers to gain a
better sense of what areas students have comprehension and where they are struggling. A bonus feature allows students to be separated into groups of similar ability, by how they answer on their phone or mobile devises.

Dissemination of ConcepTests through the use of Learning Catalytics proved to be challenging despite the perks of using the program. There were an array of problems that surfaced throughout the term that complicated the ability for students to join the session on their devises and ultimately made it impossible for the instructor to collect data. Hiccups involved dead batteries on devises, lack of devices (smart phones, tablets, or lap tops), insufficient or non-existent data plans, inability to connect to the EFSC server, and students that were unable to access the site for reasons pertaining to passcodes. Despite these problems, the majority of students preferred using PI as opposed to traditional lecture. In a survey that was given at the end of the term, most of the students stated they found Learning Catalytics to be a helpful mode of learning.

The Summer 2014 pilot served to compared two platforms to incorporate PI into the college biology classroom; educational clickers and Learning Catalytics, to see which would be the most beneficial to use in the Fall 2014 study. Each of the delivery systems were seen as beneficial by both the students and instructors. From a data collection standpoint it was more beneficial to use the educational clickers in the classroom because of the conformity of all students having the device daily and
the lack of technological problems that surfaced when using the Learning Catalytics.

Results concerning the effectiveness of administering PI in a college setting were implemented in the actual study during the fall 2014 semester to examine the effects of PI in a state college biology classroom. The treatment and control groups were consistent with each instructor teaching both a treatment and control group. Educational Clickers were used as a medium for Peer Instruction in the classroom. It’s not the technology, but the pedagogy that is being examined in this study.

**Threats to internal validity.** Internal validity refers to how well the study’s results are based on the independent variable and not an outside confounding factor. Threats to internal validity can give alternative explanations of the results that are not related to the treatment.

Quasi-experimental one-group, pretest-posttest designs offer varying degrees of effectiveness in controlling threats to internal validity. The threats and how they will be minimized are listed below (Millsap & Maydeu-Olivares, 2009).

**Maturation.** The passage of time can affect the results of a study rather than the treatment. Time itself can influence the outcome of a study. Students may learn better study habits or decrease their workload outside of school. Maturation, however, is not considered a major issue in this study because of the expected large sample size and the short duration of this study.
**History.** External events between the time of the pretest and the posttest could possibly affect the results of the study. Instructors will be informed of this potential threat and asked to keep notes on any unusual occurrences in the classroom or situations that are brought to their attention. It is not believed that history will play a factor in the results because of the short duration of this study.

**Seasonality.** Seasonality can be a factor in student performance. Depending on the time of year a student may be more or less academically motivated. For example, students who register for a course in the Fall may have a more serious mind set than a student that decides to wait until the Spring term to sign up for courses. In an effort to minimize this threat this study will take place during both the Fall and Spring semesters with control groups in each term. This should minimize this threat to internal validity.

**Testing.** In a pretest/posttest situation the students can become familiar with the test. The familiarity of seeing the material prior to taking the posttest can have an effect of increased test scores on the posttest. To minimize this threat there will be a 13 week window between the pretest and the posttest. This prolonged period of time should provide a minimal testing threat.

**Instrumentation.** Change from the pretest to the posttest can be attributed to the instrument and not the treatment. This occurs when different instruments are used for the pretest/posttest or when the instrument remains constant but is given in
a different way. For this study, the same instruments will be used for the pre-test and the posttest. All instructors will administer the tests in lab during the strategically planned weeks when extra lab time is available.

**Attrition.** Experimental mortality is a threat to studies when the students that originally took the pretest are no longer enrolled in the class and do not take the posttest. This can affect the results of the study if students with lower science ability drop out and are not part of the posttest results by leaving a higher level of students in the final results. To minimize this risk, any pretests that were completed by students who dropped the course will not be considered in the final analysis.

**Statistical Regression.** Whenever the outcome of scores vary over time, or the average score is more predominant that the low score or the high score, or when people enter in a treatment with really high or low scores, statistical regression can threaten internal validity. Students in this study are all EFSC Biological Science course students. They will not be selected on the basis of their pretest scores but instead will be verified as equivalent by these scores. Their background in science prior to EFSC will be assessed by the pretest to minimize this threat.
CHAPTER 4

Results

Introduction

This chapter is presented in three sections. The first section includes descriptive statistics associated with the sample demographics as well as data associated with the administration of the ConcepTest instrument and the Genetics Survey (Fagen, 2003). This section also includes additional information concerning the administration of these instruments. The second section presents inferential statistics resulting from testing this study’s overall model. The final section contains results of hypothesis testing as outlined in Chapter 1.

Descriptive Statistics

Overview. As reported in Chapter 3, this study was implemented in a first year biology course at a state college in Florida. To determine if the results from the respective groups could be combined into single treatments (one Peer Instruction group and one traditional group), separate independent-sample t-tests were conducted comparing achievement on a pre-test. The results indicated that there were no significant differences in mean achievement of the groups from the pretest. This allowed the researcher to justify looking deeper at individual item scores.
**Student Demographics.** To further establish group equivalency it was important to examine the student demographics in each section participating in the study in addition to pretest scores. A summary of key sample demographics to include participants’ gender, age and ethnicity are in tables 4.1, 4.2, and 4.3.

**Table 4.1** Summary of Eastern Florida State College’s Students’ Personal Characteristics for Initial Enrollment in BSCC 1010 Sections Participating in PI.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age Range</th>
<th>Sex</th>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td></td>
</tr>
<tr>
<td>At</td>
<td>19</td>
<td>18</td>
<td>34</td>
<td>20.6</td>
</tr>
<tr>
<td>Bt</td>
<td>22</td>
<td>17</td>
<td>38</td>
<td>21.6</td>
</tr>
<tr>
<td>Ct</td>
<td>24</td>
<td>17</td>
<td>37</td>
<td>20</td>
</tr>
<tr>
<td>Dt</td>
<td>25</td>
<td>17</td>
<td>29</td>
<td>19.8</td>
</tr>
<tr>
<td>Et</td>
<td>20</td>
<td>16</td>
<td>51</td>
<td>26.7</td>
</tr>
<tr>
<td>Overall</td>
<td>110</td>
<td></td>
<td></td>
<td>21.74</td>
</tr>
</tbody>
</table>

**Note:** Each letter under Group corresponds to an instructor. The t after the letter represents the treatment group. Under Ethnicity, A = Asian, B = Black, H = Hispanic, W = White.

**Table 4.2** Summary of Eastern Florida State College’s Students’ Personal Characteristics Enrolled in BSCC 1010 Sections Participating in Control Group.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age Range</th>
<th>Sex</th>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td></td>
</tr>
<tr>
<td>Ac</td>
<td>20</td>
<td>18</td>
<td>26</td>
<td>4</td>
</tr>
<tr>
<td>Bc</td>
<td>23</td>
<td>17</td>
<td>37</td>
<td>22.1</td>
</tr>
<tr>
<td>Cc</td>
<td>23</td>
<td>17</td>
<td>29</td>
<td>19.8</td>
</tr>
<tr>
<td>Dc</td>
<td>24</td>
<td>16</td>
<td>41</td>
<td>19.8</td>
</tr>
<tr>
<td>Ec</td>
<td>10</td>
<td>18</td>
<td>31</td>
<td>23.8</td>
</tr>
<tr>
<td>Overall</td>
<td>100</td>
<td></td>
<td></td>
<td>21.3</td>
</tr>
</tbody>
</table>

**Note:** Each letter under Group corresponds to an instructor. The c after the letter represents the control group. Under Ethnicity, A = Asian, B = Black, H = Hispanic, W = White.
Table 4.3 Summary of EFSC Students’ Personal Characteristics Enrolled in BSCC 1010 Sections Participating in both the Peer Instruction and Control Groups.

<table>
<thead>
<tr>
<th>Section</th>
<th>N</th>
<th>Age</th>
<th>Sex</th>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Control</td>
<td>100</td>
<td>20.6</td>
<td>32</td>
<td>67</td>
</tr>
<tr>
<td>Treatment</td>
<td>110</td>
<td>21.7</td>
<td>52</td>
<td>58</td>
</tr>
<tr>
<td>Overall</td>
<td>210</td>
<td>20.6</td>
<td>84</td>
<td>125</td>
</tr>
</tbody>
</table>

**Note:** The overall N is reflective of the classes as a whole but does not represent the number of students that filled out a consent form to participate in the study. PI stands for Peer Instruction for the treatment group.

Group membership, when examined from a gender perspective had 35% males and 65% females in the overall study. The individual treatment and control groups followed suite with the treatment having 61% females and 38% males while the control group had 68% females and 31% males, respectively. The female to male ratio was consistent with the college-wide enrollment in Biology 1 as reported in Chapter 3 on Table 3.2; 40% males to 60% females.

The predominant ethnicity was Caucasian with 52% in the treatment group, 45% in the control group and 49% in the overall study. The minority group was Asian with only 2% in the treatment group, 2% in the control group and 2% in the overall study. This group was followed by Other with 5% in the treatment group and 8% in the control group. The overall treatment group had 7% students that classified themselves as Other. The second highest group was African American which had 25% in the overall and 29% in the control group. The treatment group
had 22%. Hispanic Americans were in the middle with 17% represented in the control group, 19% represented in the treatment group and 18% overall.

In summary, group equivalency was established in regards to students’ age, gender, and ethnicity making comparisons of results more meaningful. According to Ary et.al (2010) it is necessary to establish group equivalency before embarking on a study.

Table 4.1 *Summary of Eastern Florida State College’s Students’ Personal Characteristics Enrolled in BSCC 1010 Sections Participating in Peer Instruction*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Age Range</th>
<th>Demographics</th>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>M</td>
</tr>
<tr>
<td>At</td>
<td>19</td>
<td>18</td>
<td>34</td>
<td>11</td>
</tr>
<tr>
<td>Bt</td>
<td>22</td>
<td>17</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td>Ct</td>
<td>24</td>
<td>17</td>
<td>37</td>
<td>11</td>
</tr>
<tr>
<td>Dt</td>
<td>25</td>
<td>17</td>
<td>29</td>
<td>13</td>
</tr>
<tr>
<td>Et</td>
<td>20</td>
<td>16</td>
<td>51</td>
<td>10</td>
</tr>
<tr>
<td>Overall</td>
<td>110</td>
<td>16</td>
<td>58</td>
<td>52</td>
</tr>
</tbody>
</table>

*Genetics Survey Pre-Test Scores.* As discussed in Chapter 3, a genetics survey was used as the instrument to measure student achievement. This instrument developed by Fagen (2003) contained 50 terms, 12 fill in the blank, several questions designed to address concepts covered in the course in the areas of genetics as well as background information on the students. In particular, there was one multiple-choice question designed to address a common misconception about the nature of genetic material, one free-response question, and one two-part data
interpretation question. These were all scored on a Likert scale from 1-5 as shown in Chapter 3. Table 4.4 contains summaries of students’ pre—achievement scores.

| Table 4.4 Summary of EFSC Students’ enrolled in BSCC 1010 Sections Pretest Scores. |
|-----------------------------------------------|---------|-------|
| Group                     | N       | M     | SD    |
| Treatment                 | 78      | 111   | 30    |
| Control                   | 70      | 112   | 31    |

Note: All students that turned in consent forms and took the pretest were included on this table. These scores were out of a total of 320 points.

Pre-test scores were initially compared to establish group equivalency of the respective groups (one Peer Instruction group and one traditional group). Separate independent-sample t-tests were conducted comparing achievement of pre-test scores. According to Lehman, O’Rourke, Hatcher, and Stepanski (2013), this was appropriate since the pretest scores obtained under one treatment condition are independent of (unrelated to) the pretest scores obtained under the control condition. Due to the nature of working with pre-determined groups, convenient sampling was used for the treatment and control groups. The distribution of scores around the means for both the treatment group and the control group were similar, indicating group equivalence (Lehman et. al, 2013).

Students that remained enrolled for the administration of the post-test had their pre-tests examined more closely. This was because they could eventually be matched up to a post-test. Pre-tests were examined deeper to see if the students
understanding of the terms were equivalent to their perceived familiarity with the terms given. The survey asked students to self-identify their familiarity with various terms and to actually define a subset of those terms. Students rated their familiarity on a scale of 1-5, with 1 = very poor understanding and 5 = excellent understanding of the term. The pre-tests demonstrated a lack of previous understanding with the terminology and that was consistent in both the treatment and control groups. The majority of the students did not score themselves highly on the familiarity of the pre-test terms, however these scores were higher than their understanding, as illustrated in Figures 4.1 and 4.2.

**Figure 4.1.** Comparison between the means of treatment group students’ familiarity and understanding of pretest terminology item. (n = 72)
As defined in the initial study of this instrument by Fagen (2003), all blank scores were scored as 1. Fagen acknowledged that scoring blanks with a 1 may bias the study, however, he did not believe that leaving the question blank was a clear indicator that the students did not know the answers. Due to the replicative nature of the current study, this reasoning was also adopted. Therefore, no zeros were given, so a blank or wrong answer was rated a 1 on a Likert Scale.

The difference between treatment and control groups’ familiarity were compared by taking the treatment (Pre f) and subtracting the control (Pre f). The difference between answers was minimum with a difference of .3 to a differences of -.3 between each of the individual terms. A comparison of the means of the Pre familiarity of both control and treatment groups yielded differences as seen in Figure 4.3.
Figure 4.3 Comparison between the means of the treatment and control groups on pre-test familiarity of terms. (n=134)

Of the 148 students who responded to the pre-test, only 134 responded to the post-test. Of those 134 participants, only 4% of them had ever taken a college biology course; this was the first college biology course for 96% of the students. Of the students that reported taking a previous biology course, 2% had previously taken Fundamentals of Biology, BSCC 1005, which is an introductory course that serves as an overview to Biology 1 and 2. Approximately, 69% had never taken a previous college-level science course of any type (including chemistry, physics, or science-related courses). Table 17 identifies previously taken science courses by EFSC students in the study.
Table 4.5
Science courses previously taken by student participants.

<table>
<thead>
<tr>
<th>Name of Course</th>
<th>No. of students that took the course (n)</th>
<th>Score on AP Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy and Physiology 1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Anatomy and Physiology 2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>AP Biology High School</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Astronomy</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Earth Science</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Environmental Science</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Fundamentals of Biology</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>General Biology 1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Health Science</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Medical Terminology</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Nutrition</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Oceanography</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Phlebotomy</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Survey of Anatomy and Physiology</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Physical Science</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Zoology</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>N =</td>
<td></td>
<td>42</td>
</tr>
</tbody>
</table>

Note. Of the 134 participants only 33 had taken a prior course in science. The total number of prior science courses taken was 42. All stated that they had taken the biology or its equivalent in high school. Only one had taken an AP course in high school.

Posttest Scores. Posttests were distributed after the genetics unit was complete during Week 12 of the Fall 2014 term. Students again rated their familiarity with genetics terminology on a 1-5 Likert Scale with 1 = a very poor understanding of the term and 5 = an excellent understanding. In addition to the self-identifying their familiarity with the term, they also had to define a subset of
12 of the 50 terms, to measure the accuracy of their self-assessment. In addition, there were conceptual questions from the pretest that were designed to address concepts related to genetics that were covered in the course. As with the pretest, the posttest was examined to assess the differences between the students’ familiarity with the terminology and their actual understanding using student generated definitions of the terms. As described by Fagen (2003), the self-reported familiarity increased more than the understanding of participants of the current study. Both the treatment and control groups exhibited higher scores in student ranked familiarity of terms than the fill in the blank portion revealed in their actual understanding. Some test items were left blank and as in the pre-test they were marked with a 1, representing the lowest score that a student could make on the assessment.

Fagen (2003) reported an increase in students’ self-reported familiarity of terms, by stating there was a “disconnect between what students think that they understand and what they actually understand.” This trend appeared to be the same with both the treatment and control groups as shown on Figures 4.4 - 4.6.
Figure 4.4 Comparison between the means of treatment group students’ familiarity and understanding of posttest terminology items. \((n = 72)\)

Figure 4.5. Comparison between the means of Control group students’ familiarity and understanding of posttest terminology items. \((n = 62)\)
Figure 4.6 Comparison between the means of the treatment and control groups on posttest familiarity and understanding of terms. (n=134)

**ConcepTests.** ConcepTests were given beginning in Week 9 in the treatment groups during the genetics unit, which had a duration of approximately three weeks. During the class sessions, ConcepTests were projected onto a screen and students were instructed to answer the question on their own, through the use of an educational clicker. The results were then immediately sent to the instructor’s computer, however the students could not see their answers once sent. The screen was frozen on the question, to eliminate any bias of students picking an answer selected by their peers. After 60 - 120 seconds (depending on the complexity of the question) the time ended for being able to submit an answer. For students that were not sure what the answer was, they were told to take their best guess. If less
than 80% of the students answered correctly, students were asked to discuss their answers with their group. They were not allowed to reference their books, phones, or computers. Instead, they were to discuss and defend their answer to their peers (PI). Students had up to 4 minutes to defend their answers. The question was then reopened for a second time and students could either re-enter their answer or change their answer. The initial answers (Iclick) were compared to the second submission (Pclick) to see if there was a conceptual change between the first and second answer. Each treatment group was given a total of 15 ConcepTests over the course of the Genetics Unit, which averaged between three to four ConcepTests per class session.

The answers were examined to see if there was a significant change between when the student initially answered the question on their own and after the Peer Instruction took place, by defending and discussing their answers. A one way analysis of scores was performed along with a t Test which showed a significant difference between the first time students answered the question and second time they answered after engaging in PI. Figure 4.7 demonstrates the mean increase per question for each of the treatment groups participating in PI pedagogy and using the educational clicker technology. If a question was answered with equal to or greater than 80% accuracy the score for the first answer (I click) was designated to the second answer (P click) since it was already understood by the majority of the
group and did not need to be revisited. There were instances where the second answers were lower than the first answer and that was attributed to a general lack of knowledge on the subject and stronger personalities swaying the ones that maybe were not confident in their answer. Generally speaking the number of correct answers were higher after the group discussion, refer to figures 4.7-4.10.

Due to different class sizes, each treatment group was looked at individually when analyzing the results of the first and second responses to treatment groups. Figures 4.7 – 4.10 demonstrate the differences in the number of questions that were answered correctly before and after PI for each treatment group.

![Bar chart showing comparison of correct answers before and after PI](image)

**Figure 4.7 Students answers to ConceptTests in Treatment Group A before and after PI.**

Student answers generally trended towards increased correct responses after engaging in PI and responding for the second time. In some rare cases the number...
of correct responses decreased after PI. According to Mazur et. al. 2014, a student’s may be a factor in student responses. A student with low self-efficacy in science may be more susceptible to changing a correct response and not arguing to defend it. The student’s responses in Groups B and C increase after engaging in PI.

![Bar chart showing the number of correct responses for ConcepTests in Treatment Group B before and after PI.](Image)

**Figure 4.8 Students answers to ConcepTests in Treatment Group B before and after PI.**

In the following tables Group C and D are combined because they are taught as a double section, meaning that two sections are taught at the same time. Their responses were tallied together as a whole class since they participated together. See Figure 4.9.
Figure 4.9 Students answers to ConcepTests in Treatment Group C before and after PI.

Figure 4.10 Students answers to ConcepTests in Treatment Group E before and after PI.
Students in Group E also show an increase in understanding after engaging in PI. This indicates that discussing the concepts with their peers increased their understanding of the genetics concepts.

After analyzing the answers for each class separately, all student answers for each individual question were analyzed as a whole. From this analysis a pattern was found indicating an increase in the difference between I-click and P-click as the study progressed. There was a general trend early on for I-click and P-click to be similar, however, later in the study there was a noticeable wider gap between the two. More specifically questions 1-7 had similar if not identical responses for I-click and P-click, however the questions 8-15 had a larger gap between I-click and P-click. In addition, responses from Questions 7 reflected no difference between I-click and P-click, while Question 11 and Question 14 had obvious differences.

Possible factors attributing to the differences in response from the first half of the questions to the last could be the difficulty of the questions. For example, the students may have been more familiar with the earlier sections of the chapter as opposed to the complexity of material that followed. Or the formation of the earlier questions could have been lower level questioning compared to the later questions. Although this was not an intended question in this study it is still important to report. Questions with no change in response between I-click and P-click could be the result of poorly worded questions based on simple recall where the ones with
more dramatic differences may have been more conceptual in nature. All ConcepTests can be found in Appendix A of this document, however, below are the problems in question.

Question 7: If a cell undergoes Meiosis, how many cells result after Meiosis II?

Question 11: In Labrador retrievers, different coat colors result from variations in the amount, distribution and deposition of melanin. If B codes for coat color, E codes for melanin deposition and D codes for melanin production, what color will dogs with BBEdd genotypes be? Key: B=Black b=chocolate; E = deposit color in fur, e = no deposit; D= melanin production in animal, d= no melanin production.
A. Albino  B. Black  C. Yellow  D. Chocolate

Question 14: In man, color-blindness, an inability to distinguish between red and green, is inherited as a sex-linked character on the X chromosome. It is recessive. If a normal man marries a color-blind woman, where will colorblindness likely be found in the family?
  a. All the sons
  b. All the daughters
  c. 50% sons; 50% daughters
  d. No one will be colorblind

The quality of the questions could have played role in the results. Although Question 7 could be seen as a conceptual question requiring a student to understand the steps in Meiosis and the outcomes of each, it could be seen as more of a rote form of questioning compared to Question 11 and 14. These questions do require higher Blooms Taxonomy to solve and may be the reason for the drastic scores between I-Click and P-Click. See Figure 4.11 for all aggregated section responses.
The results reflect a trend in increased student performance between clicks as the study progressed. Students overall appeared to be performing better in groups than they did individually. Redish (1999) created a framework for meaningful learning based on the work of various psychologists and educators. He believed that group work played a key role in student learning, the social learning principle. This principle states that learning is most effectively achieved through social interactions, which supports Vygotsky. The wider gap between I-click and P-click as the study advanced shows increased student scores when they worked together to solve the problems.
Inferential Statistics

**Overview.** The goal of this study was to examine the effects of Peer Instruction on State College student achievement in an introductory Biology unit in genetics. An ANCOVA was used to analyze the effect using multiple regression (MRC). This was an appropriate test since it is robust and able to determine the shared variance of PI and traditional teaching on student achievement on the posttest (Cohen and Cohen, 2003).

**Preliminary Analysis.** Before the study’s hypotheses could be tested, several preliminary analyses took place in order to ensure the data sets were appropriate and properly structured. This included equivalency testing, missing data analysis, outlier analysis, and an analysis to determine if the homogeneity of regression assumptions were upheld.

**Missing data.** It is important to account for missing data when conducting research. This can occur from missing values where there should have been a response, or from lack of completion of the posttest analysis. There were originally 148 participants that turn in consent forms and pretests. However, only 134 students completed a posttest that could be matched to a pretest. Possible reasons for not completing a posttest could have been that the student withdrew from the course, was absent the day of the posttest administration, or they may have simply
refused to fill out the posttest (since it was lengthy and no grade was tied to the assessment).

According to Cohen et al. (2003) it is an appropriate not to include subjects that did not complete the study if the N is large enough. In this case the an A Priori ANCOVA: Fixed effects, main effects and interactions power analysis was conducted on GPower giving a medium effect size of .25 and an actual Power of 0.8014112 for a sample size of 128. The sample size of 148 students was used, based on the analysis, to allow for possible mortality. The remaining sample size of 134 students was within this range so the loss of 14 participants did not affect the overall study.

**Outlier analysis.** An outlier analysis was done to remove values that were considerably larger or smaller than other values in the value set. Single outliers can have a dramatic effect on the MRC, (Gravetter & Wallnau, 2009).

Sources of outliers can occur from a variety of sources, but the two predominant ones are contaminated observations and rare cases. Error of execution, inaccurate measure of the dependent measure, errors in recording data, errors in calculation of the measures, and non-attentive participants can all result in outliers. If possible, contaminated observations should be replaced with corrected ones. Failure to remove outliers can lead to a significant model being masked by outliers and vice versa.
An outlier analysis was done with Jackknife Distances on JMP statistical software. There were three scores from both the treatment and control groups that were removed due to their Jackknife distances. This reduced the number to 128 observations, which was still in the correct range for Power.

**Regression assumptions.** According to Cohen et al. (2003), the following underlying assumptions must be satisfied in order to compete an ANCOVA. Each of these assumptions is addressed separately and how they were met is described in terms of steps taken in JMP. A valid ANCOVA model implies that parallelism of slopes exists, hence SR² is insignificant and there is no interaction.

**Linearity assumption.** Before performing the initial analysis, a correct specification of the form of the relationship between the independent variable and dependent variable, also known as the linearity assumption needed to be investigated. Linearity was satisfied by performing a Bivariate Fit of Residuals of Y = Posttests by Predicted Y = Posttests.

**Independent variables.** Correct specification of the independent variable in the regression model also needed to be examined. This is to insure that all variables identified are included in the model. This assumption was met by performing a Bivariate Fit of Residuals on Y = Residuals of Y of X² and X³ on X = Residuals of X¹ given X² and X³.
Homogeneity of regression assumption. The homogeneity of regression assumption was upheld by a dummy variable linear regression with interaction terms in the model. The slopes of the lines were close enough to uphold the assumption of homogeneity in the model.

Independence of Residuals. Independence of Residuals states that the covariate is independent of the treatment effects. A Bivariate Fit of Residuals was performed in a scatterplot and it was determined that the residuals of the observations were independent of one another. This assumption was met.

Normality of residuals. Normality of residuals, which states that there is a normal distribution of residuals around the regression line. This makes it possible to evaluate the statistical significance of the relationship between X and Y as reflected by the regression line. The normality of residuals was met by examining a univariate plot of the posttest residuals and normal quantile plot.

Primary analysis. This section is broken down into four parts to address each of the Research Questions from Chapter 1. The first part addresses student achievement on the posttest by both the treatment and control groups. The second looks at retention in the PI groups versus the traditional groups. The third part reports on interaction effect with both gender and academic characteristics with PI. The fourth part speaks to the differences between the first and second time students answered their ConcepTest questions after engaging in PI.
**ANCOVA analysis on student achievement.**

*Overview.* The Analysis of Covariance (ANCOVA) is a technique that uses both analysis of variance and regression analysis. The purpose is to increase the precision of comparisons between groups by accounting to variation on important predictive variables and to "adjust" comparisons between groups for imbalances in important predictive variables between groups. An ANCOVA was performed to investigate the shared variance of the PI and control groups on achievement in the genetics surveys that were given as both a pretest and posttest.

*Use of a pre-assessment.* The pre-test was used to get a baseline of where the students were at the beginning of the term and to compare the growth at the end of the genetics unit. The mean scores on the pretest and the posttest were assessed for both the PI group and the control group. The difference in scores between the pre and posttest show the learning gains of the students from the first time they took the Genetics Survey by Fagen (2003) and the second time they took the survey. The mean score of the pretest was compared to the mean score of the posttest. The mean difference was obtained by calculating, \( M_{\text{posttest}} - M_{\text{pretest}} = M_{\text{difference in scores}} \). See Table 4.6.
Table 4.6
Genetics Survey Change in Score

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>$M_{pre}$</th>
<th>$M_{post}$</th>
<th>$M_{Diff}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>62</td>
<td>107.6</td>
<td>188.1</td>
<td>80.5</td>
</tr>
<tr>
<td>Treatment</td>
<td>72</td>
<td>114</td>
<td>200.3</td>
<td>86.3</td>
</tr>
<tr>
<td>Overall</td>
<td>134</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Change in score refers to mean difference. $M_{pre}$ refers to mean number of items scored correctly for each group on the Pre Genetics Survey. $M_{post}$ refers to the mean number of items scored correctly for each group on the Post Genetics Survey. $M_{Diff}$ represents the difference between the Post Genetics Survey and Pre Genetics Survey means (i.e., Post Genetics Survey mean – Pre Genetics Survey mean). The difference is the knowledge gained.

**Student achievement.** An ANOVA was run as a comparison to see what the model would look like without the covariate. The $R^2$ value represented the amount of variance in the achievement on posttest scores. The $R^2$ value was 0.033466 and implies that 3.34% of the variance is associated with achievement on the posttest. In other words, 3.34% of the information can perfectly predict $Y$, achievement on the posttest.

The prediction equation of the overall model was $\hat{Y} = -6.31X + 190.76$. The model was significant with $F(1, 126) = 4.36$, $p < 0.0387^*$. The linear relationship between traditional teaching and Peer Instruction is not likely to be zero in the population with less than 5-100 chance of doing so erroneously assuming $p < .05$. The $F$ value exceeds 3.92 (Gravetter & Wallnau, 2009) therefore we conclude the independent variable, Peer Instruction, had a significant effect on achievement.
The regression coefficient was -6.31, which means that students in the traditional group averaged 6 points less than students in the PI group. This was significant $t(126) = -209, p = 0.0387$. The regression constant was 190.76, which means that the PI group averaged approximately 191 points on the posttest. This was significant, $t(126) = 63.08, p < .0001$.

When looking at the group membership in the study, the control group scored on average 184 points on the posttest. The end point $X^2$ is at about 191 points and the end point for $X^1$ is at about 184 points. For $X^1$ (Control Group), $\hat{Y} = -6.31 (1) + 190.76 = 184.45$. This is the average posttest score for the traditional group.

For $X^2 \hat{Y} = -6.31 (0) + 190.76 = 190.76$. This is the average posttest score for the Peer Instruction group.

The overall conclusion of the ANOVA, when looking at the results is that the model is significant. $R^2 .03$ indicates that if we were to apply the sample’s prediction equation to the population, or to another sample acquired from the same population, then we would be able to explain about 3% of the $Y$ variance in the population or from the new sample, (Cohen et. al, 2003). In other words, Peer Instruction provided 3% of the information we needed to accurately predict achievement on the posttest.
Afterwards an ANCOVA was run to control for covariates and conduct follow-up tests between groups. The added covariate was $X^1 = \text{Pretests}$. The model was significant at $P < .0001$. The $R^2$ was .204238 which accounts for 20% of the information needed to perfectly predict $Y$, achievement on the posttest. Although the overall model was significant, $F(2, 125) = 16.04, p < 0.0001^*$, the treatment no longer yielded a significant result with $p = .0687$ at the alpha level of .05. The regression equation for the final model was $\hat{Y} = .44X_1 -5.08X_2 + 131.90$.

The regression coefficient for achievement in the presence of the pretests was .44 which implies the students’ scores in the presence of the pretest were .44 points above the overall un-weighted grand mean, consisting of scores of the treatment and control groups on the pretest, and the scores of the treatment and control groups on the posttest.

The regression coefficient for PI was -5.08, which means the treatment averaged approximately 5.08 points lower than the overall un-weighted grand mean consisting of the scores on the pretest and the scores on the posttest.

The regression constant was 131.90. This means that the overall un-weighted grand mean score was approximately 132 points overall in both treatment and control groups on the pre and posttests.
An ANCOVA was appropriate for the study because the focus is on the posttest score. Pretest scores were a possible confounding effect, and act as a covariate. The ANCOVA allowed for control of the carryover from the pre-test scores. A summary of the results can be found in Figure 4.8.

Table 4.7

<table>
<thead>
<tr>
<th>Variables</th>
<th>R2</th>
<th>df</th>
<th>t</th>
<th>q</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.204238</td>
<td>2</td>
<td>11.28</td>
<td>0.05</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>X₁ = Pre-tests</td>
<td>0.17</td>
<td>1</td>
<td>5.18</td>
<td>0.05</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>X₂ = PI</td>
<td>0.034</td>
<td>1</td>
<td>-1.84</td>
<td>0.05</td>
<td>0.0687</td>
</tr>
</tbody>
</table>

Note. N = 128. Overall represents the whole model with both pretests and PI in the model. PI was no longer significant with Pre-tests in the model.

Student retention. Student retention in the classes with Peer Instruction were compared with the classes that were taught in the traditional method. The number of student withdraws from the beginning of the term to the drop date were considered. An independent measures t Test was used to see the difference in the number of students that were retained in both groups. This was not significant t(128) = - 0.53238, p > 0.5954. There was no evidence that the PI increases retention.

The percent of attrition from the beginning of the term to the drop date was 3%. Of the 211 students that started the term, 204 remained after the October 30th drop date. The drop date is the deadline for students to withdraw from the class
with a “W” and not a grade. Of the 3% that withdrew, 43% were from the treatment group and 57% were from the control group. However it is important to note that PI was not applied until much later in the semester. Had PI been incorporated at the beginning of the term and used throughout the term there may have been different results.

Figure 4.12 Student retention by group membership.

**Sex and academic characteristics on achievement.** An interaction effect between sex and PI and between academic characteristics and PI was examined. This was done to see if certain groups do better with PI or traditional teaching methods. To further investigate all research factors were looked at to examine the interaction effect between the dependent variable and all the independent variables.
The independent variables included the covariate (the pretest) and research factors (gender and academic characteristics). The posttest was the dependent variable.

The independent variables were organized into three functional sets: Set A (covariate), Set B (research factors) and Set C (interaction), which is the product of the covariate and research factor (Set A X Set B). The posttest is the dependent measure and will comprise Set D, the dependent variable set. The variables and set memberships are summarized in Table 4.8.

### Table 4.8

<table>
<thead>
<tr>
<th>Set Entering Model</th>
<th>Cumulative $R^2$</th>
<th>$I_a = \sum r_i^2$</th>
<th>dfi</th>
<th>$F_i$</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.165</td>
<td>3,125</td>
<td></td>
<td>&lt; .0001</td>
<td></td>
</tr>
<tr>
<td>B = Gender</td>
<td>0.005</td>
<td>0.005</td>
<td>1, 127</td>
<td>0.58</td>
<td>0.4487</td>
</tr>
<tr>
<td>C = Prior Science Course Work</td>
<td>0.006</td>
<td>0.001</td>
<td>1, 127</td>
<td>0.126</td>
<td>0.6695</td>
</tr>
<tr>
<td>A = Covariate (Interaction Effect)</td>
<td>0.165</td>
<td>0.159</td>
<td>3, 125</td>
<td>11.8</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

*Note.* Overall represents the overall model with all variables that correspond to the targeted factors. Set A, the covariate = pretest scores. Set B = Gender and Set C = Prior Science Experience. The interaction effect between Sets A, B and C are considered.

In a simultaneous regression analysis, all the variables are added to the model at the same time. This means $R^2_{\text{y,123}} \neq \sum r_i^2$ because it does not provide a full accounting of the overall $R^2$; there is something always missing. The partial correlations have correlation with Y in the presence of all the other independent variables.
A hierarchical regression analysis was performed to provide a unique partitioning of the Y variance by entering the independent variables one at a time in a specific order. The first variable into the model was able to claim as much of the variance as possible. When any future variable was added it could only add to the variance of Y that was not already explained by the previous variable entered into the model. From the last regression it was observed that pre-tests were significant. For this reason pre-tests were entered last so that the other two variables, sex and prior science experience, could be scrutinized more closely.

The overall model was significant with $F(3, 125) = 8.26$, $p < .0001$. The collective contribution of the sets entered in the hierarchical order B (gender), C (prior science coursework), and A (Pretests) accounted for 1.7% of the variability in the posttest scores. Afterwards each set was looked at individually to identify all significant variables.

Set B was defined by gender. Gender accounted for 0.5% of the knowledge of variance for posttest scores when entered into the model by itself, before Sets C (Prior Science Courses) and A (Pretest Scores). This was not significant $F(1, 127) = 0.58$, $p = 0.45$.

When Set C, defined by prior science coursework in college, was introduced to the model with Set B (Gender) it accounted for another 0.01% of the variability of posttest scores. This was not significant, $F(1, 127) = .126$, $p = 0.65$. 
The covariate which was Set A (Pretest Scores) accounted for an additional 0.159% of the variance when analyzed in the presence of gender and prior coursework in science. This was significant $F(1, 127) = .126, p < .0001$.

If these sets had more than one variable in each we would only be able to look into Set A individually because it is the only one that is significant. If Sets B or C were looked at individually there would be risk of committing a Type I Error by inflating the alpha values.

The overall conclusion about the relationship between posttest scores and the predictors is that Set A is the best predictor for Posttest scores. This was the only significant set and is driven by a single variable. Sets B and C were not very good indicators for Posttest scores, even though they were put into the model first. Although the model is significant, I do not believe the given predictors are adequate for predicting posttest scores, since only one was significant. Also 99% of the variance is being explained by something other than the factors considered.

**Initial response vs. secondary response.** An independent measures t Test was performed to look at the differences in responses from treatment group students before and after Peer Instruction. Student answers were collected through the use of educational clickers and stored on the instructors’ computers. After responding initially to the questions on their own, students were allowed to work in
small groups and defend their answers through the process of PI, if less than 80% of the class got the question correct.

An independent measures t Test on all of the classes, individually, showed a significant difference in correct answers after the students participated in Peer Instruction, indicating a conceptual change between the first and second time they answered the questions. See Table 4.9.

**Table 4.9 Clicker Responses**

<table>
<thead>
<tr>
<th>Group</th>
<th>Initial</th>
<th>Post</th>
<th>Initial</th>
<th>Post</th>
<th>Initial</th>
<th>Post</th>
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<th>Post</th>
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<td>18</td>
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<td>17</td>
<td>27</td>
<td>37</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

N = 16

Mean 10.75

Std Dev 3.04
Results of Hypothesis Testing

The following hypotheses from Chapter 1 have been restated in null form. A summary of their statistical results are stated below.

**Hypothesis 1.** Instructional strategies will not have a significant effect on state college students’ achievement (ACH).

**Hypothesis 1a.** There will be no significant difference in the achievement of students who participate in PI of the targeted science concepts than those who participate in the traditional approach to learning.

An ANCOVA was performed to control for the pretest. Although the overall model, $\hat{Y} = 0.44X_1 - 5.08X_2 + 131.90$ was significant with $F(2, 125) = 16.04$, $p < 0.0001^*$, the treatment no longer yielded a significant result with $p = 0.0687$ at the alpha level of .05. Consequently, this hypothesis was not rejected. There was no statistical difference in achievement between students who engaged in Peer Instruction and those who were taught traditionally.

**Hypothesis 1b.** There will be no significant difference in student retention between students who participate in PI and students who participate in traditional teaching methods.

An independent measures t Test was used to see the difference in the number of students that were retained in both the treatment and control groups. This was not significant $t(128) = -0.53238$, $p = 0.5954$. There was no evidence
that the PI increases retention in biology. Consequently this hypothesis was not rejected.

**Hypothesis 2.** Students’ gender will not have a significant effect on science achievement.

Student gender was investigated via a hierarchical regression analysis. Gender was added into the model first and accounted for .5% of the variability of posttest scores. Upon analysis, gender did not yield significant results with F(1, 127) = 0.58, p = 0.45. Consequently the hypothesis was not rejected. Student gender had no significant effect on student achievement.

**Hypothesis 3.** There will be no positive correlation between students’ academic characteristics (i.e., number of science courses taken before BSCC 1010) and science achievement.

Students’ prior postsecondary coursework in science was considered by performing a hierarchical regression analysis. When prior science coursework was introduced to the model with Set B (Gender) it accounted for another.1% of the variability of posttest scores. This was not significant, F(1, 127) = .2064, p = 0.65. There was no positive correlation between students’ academic characteristics and science achievement. The null hypothesis was not rejected.
**Hypothesis 4.** There will be no significant increase in correct answers among students’ initial answer and second answer on their ConcepTest.

Students’ ConcepTest answers were examined for between the first and second time they responded. There was a significant increase in the number of correct from the first and second response with \( p = .0008 \). In this case the null hypothesis was rejected.
CHAPTER 5
Conclusions, Implications, and Recommendations

Summary of Study

The purpose of this study was to determine the effects of instructional strategies on science achievement of State College Biological Science students in an introductory unit in genetics. The sample consisted of 134 students enrolled in BSCC 1010 General Biology 1 during the 2014 Fall semester. Students registered for the biology course that best fit their schedule. Depending on which class they signed up for they were in one of two groups; treatment groups that incorporated ConcepTests for Peer Instruction throughout lecture; and control groups that were taught with traditional lecture.

The study was a quasi-experimental pretest/posttest design. Implementation occurred during a unit in genetics, which occurred Week 9 and had a 3 week duration. Both the treatment and control groups were found to be statistically equivalent based on pretest scores, age, gender, and previous experience in science.

Pretests and consent forms were administered during Week 2 of the Fall 2014 semester and the posttests were administered during Week 12. Both pretests and posttests were administered by the respective instructor during normally scheduled class time. All tests were returned to the principle investigator for grading purposes. After the instruments were graded, the data was input into Excel
spreadsheets, and then transferred into the statistical software program JMP. An ANCOVA was used to evaluate achievement in courses taught with PI, along with a hierarchical regression to assess interaction effects of the independent variables with PI. Results presented in Chapter 4 will be further discussed in the next section. All instruments, data tables, figures and raw data can be found in the appendix portion of this dissertation.

Summary of Findings

Before investigating the study hypotheses, the data sets were examined for missing data, outliers, and compliance with regression assumptions. Originally 148 participants turned in consent forms and completed the pretests. However, only 134 students completed a posttest that could be matched to a pretest and were subsequently dropped. Of the remaining 134 students, 6 had outlier data; 3 from the treatment group and 3 from the control group. These data points were erroneously different than the rest of the data and were left out of the final analysis. This left a final sample size of 128 students with complete data in all respects. This final data set was compliant with the regression assumptions and was used in the findings of overall study.

Conclusions and Inferences

This section discusses the research questions and their corresponding hypotheses in the study. The discussion includes a summary of the findings in
response to each question, interpretations of the results, and some probable explanations for the results obtained. Results are summarized in Table 5.1.

Table 5.1  
**Summary of Hypothesis Test Results**

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1a Achievement * PI = 0</td>
<td>Fail to Reject</td>
</tr>
<tr>
<td>H1b Retention * PI = 0</td>
<td>Fail to Reject</td>
</tr>
<tr>
<td>H2 Gender * Achievement = 0</td>
<td>Fail to Reject</td>
</tr>
<tr>
<td>H3 Academic Characteristics * Achievement = 0</td>
<td>Fail to Reject</td>
</tr>
<tr>
<td>H4 Click 1 - Click 2 = 0</td>
<td>Reject</td>
</tr>
</tbody>
</table>

**Research question 1a.** What is the effect of Peer Instruction on state college students’ science achievement?

After completion of the Genetics unit on Week 10, student achievement was measured by the Genetics Survey Posttest (Fagen 2003). A valid and significant ANCOVA model yielded the regression equation, \( \hat{Y} = .44X_1 - 5.08X_2 + 131.90 \).

The model was significant, \( F(2, 125) = 16.04, p < 0.0001^* \).

The collective contribution of PI in the presence of pretest scores explained 3% of the variation on student achievement. Although the effects of using PI in the classroom did show improvement in posttest scores compared to the traditional teaching methods, it was not statistically significant with \( p = .0687 \).
Numerous studies by Mazur, most notably Crouch and Mazur’s 10 year study using PI in the classroom (2001), document an increase in student achievement in the area of Physics when using PI in the classroom. In addition to the studies at Harvard, Lasry, Mazur, and Watkins (2008) were able to show a significant increase in student scores using PI at a two year college in physics. One plausible explanation for the lack of statistical significance in this study may be the short duration of the study. Mazur et al integrated PI into the entire semester, while this study was incorporated into a 3 week unit. The intervention only covered one unit out of six that are covered over course of the term. More time utilizing PI in the classroom may have led to significant results.

Another explanation could be sample size after removing outliers \(N=128\). Although this was appropriate for the apriori power analysis, an increased sample size would increase power. Increasing power would increase the probability of significant results. However, Mazur et al (2008) used a similar sample size at John Abbot College and yielded significant results.

One could argue that Physics concepts are more mathematical in nature which in turn produces more concrete answers; whereas biology can be more subjective. The amount of terminology that is needed in order to fully understand concepts in biology could be a challenging hurdle for PI in the biological classroom.
**Research question 1b.** What is the effect of Peer Instruction on state college students’ retention in science courses?

In order to see if PI had an observable and quantifiable effect on student retention in BSCC 1010, the number of students that started the term were compared with the number of students that withdrew by the withdraw deadline. Of the initial number of students registered in the PI group at the beginning of the term (N = 110), less than 3% dropped by the withdraw deadline (N = 3). In comparison, the students in registered in the control group (N = 201) 4% dropped by the withdraw deadline (N =4). The total number of students overall that remained was 204 out of the original 211. Out of the students that withdrew, 43% were from the treatment group and 57% were from the control group. This was not significant t(128) = - 0.53238, p > 0.5954. There was no evidence that the PI increases retention in biology.

The withdraw deadline was chosen because it was at the end of Week 11, which was the last week of the Genetics unit and the last week PI was used in the classroom. Posttests were given Week 12. In other PI studies, the final exam was used for gauging retention, however, the month after the posttest would not be relevant since instructors did not use PI after the withdraw deadline.

Lasry, Mazur, and Watkins (2008) were able to demonstrate a significant increase in student retention using PI at a two year college in physics. As pointed
out earlier, a longer duration of PI may have been beneficial for student retention. Starting at the beginning of the term would have given a better representation of student retention because by time this study started many of the students that decided to drop had already withdrawn from the course. Even though Genetics is one of the longer units in biology it is still only a small portion of the coursework and it did not start until well after the semester set in during Week 9.

The overall retention in Biology I was 96.6% at the withdraw deadline, however, overall retention at the end of the term was 92%.

**Research question 2.** What interaction effect exists, if any, among Peer Instruction and sex with state college students’ performance in science?

Student sex was analyzed via a hierarchical regression analysis. Gender was added into the model first so it could claim as much of R as possible, however, it only accounted for .5% of the variability of posttest scores. Upon analysis, sex did not yield significant results with F(1, 127) = 0.58, p = 0.45.

As noted in Chapter 2, gender achievement gaps in science as closed significantly over the last decade, (Lorah & Ndum, 2013). Though there have been inequalities in STEM courses between the sexes, that have driven studies for decades (Jones et al, 2000), ability to achieve science success is not attributed to gender as much as it is to attitudes towards science. There was not an instrument to analyze student attitudes towards science in this study. Only sex was examined in
respect to student achievement. On the basis of sex there was no interaction effect between sex and achievement in science.

**Research question 3.** What interaction effect exists, if any, among Peer Instruction and students’ academic characteristics, as defined in number nine, on student performance?

A hierarchical regression analysis was performed to examine students’ prior postsecondary coursework in science and PI. When prior science coursework was introduced into the model with Set B (Gender) it accounted for 1% of the variability of posttest scores. This was not significant, $F(1, 127) = 0.2064, p = 0.65$. There was no positive correlation between students’ academic characteristics and science achievement. The students’ backgrounds were homogeneous and may account for why prior coursework did not contribute to differences in their performance.

The number of students that took prior coursework in science was 33 students. There were 19 students in the control group and 14 students in the treatment group that had taken prior postsecondary science courses before BSCC 1010. There were a total of 42 courses taken.

BSCC 1010 is a first year Biology course so most students would not have previous coursework in science, unless they took AP science courses in high school. Only one student reported taking AP biology and that student reported a 4
which would be passing on the AP exam. Some universities do not accept a 4 on the AP exam, so it is possible that student was retaking the course for an “A”. Another possible scenario is that they did not accurately report their score.

Due to the lack of students that acquired previous coursework in science, this sample of students did not vary substantially. The students’ academic characteristics were not that different; it was almost a homogeneous group. They did not represent the ideal heterogeneity to test the relationship between previous credits in science earned and post-achievement mastery.

**Research question 4.** How do student responses differ between the first time the question is posed and the final group consensus?

Differences in responses from treatment group students were examined before and after Peer Instruction. After responding initially to the questions on their own, student answers were collected by means of electronic clickers for instant evaluation by the instructor. If less than 80% of the class answered correctly, they were instructed to work in small groups and defend their answers (PI).

An independent measures t Test on all of the classes, individually, showed a significant increase, p = .0008, in correct answers after the students participated in Peer Instruction, as seen on Table 4.8. This suggests conceptual change between the first and second time students answered the conceptual questions.
There were instances where student answers would decline after participating in (PI). Crouch and Mazur (2001) reported this occurrence in their Fall 1997 group where 6% of the participants changed from a correct answer to an incorrect answer in their analysis of initial and post ConcepTest answers.

**Implications**

This section is composed of two parts. The first part compares the current study’s result to those of past studies, which were presented in Chapter 2. The results are also related to the theoretical foundations from which the study’s hypotheses were deduced. The second part discusses the implications of this study relative to educational practice.

This study provided a method to analyze the potential impact of using Peer Instruction to increase student performance and understanding of genetics concepts through the use of ConcepTests in a state college general biology course. There were 10 classes used in the Fall 2014 semester; 5 control groups; 5 treatment groups. A total of 134 students participated in the study to its completion. An increase in student performance in the treatment group on pretest/posttests was not significant, $p = .0687$. Student retention, gender, and previous academic coursework was not found to be significant.

The opportunity for students to discuss concepts in class was used in the form of PI and was evaluated with genetics concepts in the form of ConcepTests.
Students’ correct responses before and after engaging in PI increased and was significant $p = .0008$. According to Ormond (2012), students control their own learning through cognitive processes in which they engage. Students who are mentally engaged will learn more effectively than those who are not. Peer interaction, class discussions, and authentic activities allow learners to think more effectively by acquiring the basic cognitive tools from classroom activities in the academic discipline. Students learn more and can remember more when they talk about their experiences or have learning tasks in which they are actively engaged.

There have been many studies by Mazur in the area of physics that address Peer Instruction as an alternative teaching technique to enhance student learning of difficult concepts. Other science disciplines in the biological sciences have answered surveys about their experiences with using PI, however, at the time of this study, the researcher was not able to find any publications of their results in the classroom.

The limited research in the area of biology using PI in the classroom motivated this study. Knight and Wood (2005) documented partially incorporating interactive teaching techniques to include PI in their University of Colorado biology classes, as reported in Chapter 2. PI, however, was one of many variables used as interactive engagement techniques in their study. Their study tested a variety of cooperative learning strategies on biology students which included JITT
methods, homework and cooperative group activities in the form of concept maps and journal articles as part of the experiment. Their findings paralleled the results found in other disciplines, by replacing some of the lecturing with interactive engagement and cooperative learning. Students were given a pretest at the beginning of the term that they received points for completing. At the end of the term the post-test was given as 15 questions embedded in their final exam. Course points include homework, group work, and in-class participation.

In the present study, students were not graded on their participation in PI or given credit for their pretests/posttests. Perhaps if their grades were linked to this pedagogy they may have put more thought or effort into pretests and posttests. In the studies that have utilized PI as a pedagogy for conceptual learning, the entire term was dedicated to this type of instruction. In the future it would be interesting to incorporate PI as a semester long practice to see if it increases significant student learning gains. Additional strategies like JITT may enhance student learning and require them to be a more active participant outside of the classroom in their learning.

The increase in correct responses to ConcepTest questions using PI could be attributed to the concept of Social Cognitive Theory, introduced by Albert Bandura. It states people learn through observation and are more likely to model behaviors of others that are perceived as similar to themselves. If they see a peer successfully
complete a task they may feel like they too can achieve that task. This leads to a student’s self-efficacy or belief that they are able to accomplish the goal. A person’s perceptions and attitudes about his or her ability to do something is an important construct that can influence cognitive development (Ormrod, 2012).

Leonard (2000) discussed the importance of constructivist learning. He stated that knowledge is actively built and the function of cognition is adaptive. By having students construct their own knowledge students are more engaged in learning and are more likely to understand concepts. Mazur noticed his students were more likely to learn concepts that they did not understand from their peers who just learned the material than they were from him (Hanford, 2011). This correlates with both Bandura’s Social Cognitive Theory and Vygotsky’s sociocultural theory. Constructivism allows students to be in control of their learning and with PI students are at the helm in control of their thinking. Metacognition plays a significant role by having students think about why they have a particular understanding and reflect those thoughts with their groups while engaging in Peer Instruction (PI). In a study by Gooding & Metz (2009) it was found that student-centered learning and inquiry facilitated by the teacher allows students to have a better scientific understanding by recognizing discrepancies between their understanding and the content or concepts being studied. The use of Peer Instruction promotes metacognition by allowing students to evaluate their
scientific thinking. Although some of the findings in this study were not statistically significant, the difference in scores between the pre and posttest showed the learning gains of the students from the first time they took the Genetics Survey by Fagen (2003) and the second time they took the survey. The mean score of the pretest was compared to the mean score of the posttest. The mean difference of 6 points was obtained by calculating, $M_{\text{posttest}} - M_{\text{Pretest}} = M_{\text{difference in scores}}$. See Table 4.7.

**Generalizability, Limitations, and Delimitations**

**Generalizability.** The external validity or generalizability of this study can be considered from both a population generalizability and ecological generalizability viewpoint. Population generalizability is how well the sample represents the target population. As stated in Chapter 3, the target population was all State College students in Florida enrolled in General Biology 1. The accessible population was all students at EFSC, located on 5 different campuses in Brevard County. The sample was taken from the Palm Bay Campus located on the southernmost end of the county. Based on the sample’s student demographics, the study results are generalizable to the other EFSC campuses (See Tables 3.1 & 3.2).

Ecological generalizability refers to the degree to which the research can be applied to a non-research settings or condition (Fraenkel & Wallen, 2003).
In this case, how generalizable would these results be to other institutions that commence 4+ year degrees? The ecological generalizability of PI has been shown in the area of physics. In a study by Fagan (2003) instructors teaching a variety of courses from different institutions all over the world were surveyed on their experiences with PI in the classroom. Fagen’s analysis revealed positive experiences using PI however, at the point of researching this topic and to the best knowledge of the researcher, other than Knight and Wood (2005) that gradually transitioned to an interactive teaching format, there were no publications of using PI in a biology classroom. This study was unique in that the population was composed of students at a state college studying a genetics unit in biology.

**Study limitations and delimitations.** Limitations and delimitations should be considered when reviewing the result of any educational study. Limitations are outside of the researchers control and delimitations are self-imposed by the researcher on the study to make the study manageable.

**Limitations.** The following limitations were considered.

1. Sampling. The sample of participants may be a limitation in this study since the students are signing up for the courses on their own which makes random sampling impossible.
2. Demographics. Student demographics may be a limitation since many of the students are from the Palm Bay area and statistically originate from a similar socioeconomic backgrounds.

3. Curriculum. The course curriculum is targeted for Biology I. The objectives and curriculum standards are established by the State of Florida and generalization should be relevant to course curriculum.

**Delimitations.** The following delimitations were considered.

1. Learning styles. Students’ learning styles were not assessed in this study and therefore delivery of instruction could have an effect on student performance.

2. Scientific concepts. Concepts investigated were limited to genetics concepts. This may have different results in other areas of biology.

3. Duration. The duration of the study was limited to 1 academic semester. Time could have had an effect on the results of this proposed study, however many studies in education have the same proposed time period or even shorter duration and still provide useful implications for classroom settings.

4. There were three instructors participating in this study. They are all considered to be experts in their field. The purpose, procedures and
scope of the study was explained to the instructors to increase
treatment uniformity.

5. The achievement instrument created by Fagen (2003) was used to
assess student gains in the area of genetics. The pretest was used to
establish equivalency.

**Recommendations for Research and Practice**

After completing the study there were questions that arose that would be
interesting to investigate in the future when investigating the use of PI in a state
college biology course. It would also be noteworthy to keep in mind some of the
study’s limitations and delimitations discussed earlier in the chapter. They are
addressed below.

**Recommendations for research relative to study limitations.**

1. Sampling was done by using pre-determined groups dependent on students’
schedules. In a college setting random sampling that is found in a true
experimental design is not feasible since students sign up for the
convenience of their schedules. It would be advantageous for instructors at
other state colleges to repeat the study and see if they did indeed have the
same results.

2. Student demographics were obtained from the southernmost campus of
ESFC in Palm Bay. The homogeneity of the group was effective with
respect to equality of groups but may have had an effect on the outcome due to our student base. A replication study in a different demographic area in the United States would be useful to see if the results are the same in a more diverse group.

3. The course curriculum was relevant regarding the objectives and standards established by the State of Florida. Generalization should be relevant to course curriculum however follow-up studies at another State College institution would be helpful to confirm these findings.

**Recommendations for research relative to study delimitations.**

1. Learning Styles were not assessed during this study so it is possible that a student’s learning style could either help or hinder their success when learning using PI in biology. It would be advisable to add a learning styles inventory to future studies.

2. Curriculum chosen for this study was limited to the genetics unit and did not cover other areas of study in the course. It would be beneficial to use Peer Instruction throughout the entire course to see if there is an increase in student achievement for all the science concepts covered in the class.

3. The duration of this study was over one semester, however the treatment was only for a three week period. Incorporating Peer Instruction into
the entire semester may be advantageous and could possibly give different results when used for a longer duration. It is recommended that PI be used over an entire semester and that it would incorporate all of the biological concepts covered during the term.

4. The instructors in this course were considered experts in their field, however, there could be a teacher effect that went undetected. It would be advisable to add another component to future studies to look at teacher attributes. This could be done by adding another component to the study by interviewing teachers or giving them a survey.

5. The instrument used was designed by Fagen (2003). There were some minor adjustments to make the questions more relevant to the students at EFSC. The grading of this instrument was timely and if there were more students involved it may be advisable to put the survey into an electronic form such as Survey Monkey, Boomerang, or another on-line survey forum so that surveys could be tallied electronically.

**Recommendations for future research and practice.**

This study was based on Mazur’s study incorporating PI at Harvard University with his Physics students. There were several aspects of this study that may useful for follow-up in future studies.
1. Fagen set out to examine the effects of PI in a biology course but discovered there was not an instrument comparable to the Force Concept Inventory (FCI) used in Mazur’s studies. He created an instrument that could be used as a pretest and posttest for future studies in the area of biology. He suggested that gender and previous coursework would be interesting areas to address in a future study of PI in the area of Biology. This was analyzed in this study, however the results were not significant. Student attitudes towards science may have a more significant effect on student achievement than gender and previous coursework in biology. This is especially true since BSCC 1010 is a freshman science course, so there are not a lot of other courses that could be taken before Biology 1. A student’s attitude toward science may have more of an impact on their success in a course. This could be given in the form of a survey or interview depending on the number of students.

2. Mazur et al. reported success using PI in regards to student academic achievement. In all of the studies PI was used over the entire semester. It is recommended that PI is incorporated over the entire term. This was also mentioned as a delimitation and should be considered in future studies.
3. Students were not given credit for ConcepTests, pretests, or posttests. Students may have taken these instruments more seriously if they were assigned a grade. It is advisable that credit is given to students in the future when doing these activities.

4. Some of the instructors complained that there was not enough time to teach all the material and to use PI in the classroom. Knight and Wood incorporated Just-in-Time Teaching (JITT) into their classes. This is more of a flipped classroom where students learn on their own and come to the classroom with questions that they submit to the instructor. This may be an effective way to cover all the material and incorporate a more interactive classroom using PI. This would be a beneficial way to address students’ misconceptions and make the learning their own.

5. Although the sample size was in compliance with the A priori Power Analysis it may be interesting to see if an increased sample size would give different results. This may be done by doing back to back studies that last more than one semester and should be considered in subsequent studies.
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Appendix A

Instruments
Biology 1 BSCC 1010 – Pretest  This survey is designed to collect information on your previous experience in biology. You can help the teaching staff gain a better sense of your preparation and experience by completing this survey. Your responses on this survey will have no bearing on your grade. However, you will positively affect your own experience in this course by responding thoughtfully and honestly. Thanks for your feedback!

**Terminology:** The following table contains vocabulary taken from the glossary in the back of the text and represents some of the important terms in genetics. For each word, indicate your familiarity with the term in the context of biology and genetics (several have non-scientific meaning as well) on a scale of 1-5 as shown. Remember that we do not expect or assume you to know all – or even any- of these terms prior to the course.

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Now please briefly define the following words or describe their biological significance.

<table>
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Concepts

Please answer the following multiple choice and short answer questions. Please provide an answer for each question, even if it is a wild guess. Remember, you are not being graded on this survey.

1. How does the genetic material in a skin cell compare to the genetic material in a liver cell?
   c. The genetic material is identical in both cells
   f. The genetic material is mostly similar, but differs somewhat
   g. Different amount of genetic material but can't tell how
   h. Different content of genetic matter

2. What does it mean at the molecular level to say that a trait is dominant?

1. You are asked to serve on a jury considering a paternity case. A single mother of a baby is trying to get the father to pay his share of child support. The man she has identified as the baby's father denies the charge. They agree to perform a genetic test; they obtain DNA samples from the child, mother, and accused father and look at the length of DNA fragments resulting from a restriction enzyme digest in a certain region of the human genome. The child shares some of the DNA fragments with the mother but also has several fragments not shown in the mother's sample.

   (a) If the man’s sample contains fragments which match up exactly with those of the mother, what, if anything, could you conclude about the accused man's paternity?

   (b) If the man's sample contains fragments which match up with those of the child not present in the mother, what, if anything, would you conclude about the accused man's paternity?
Background

Please indicate how many years of each of the following subjects you took in high school and whether or not you took the Advanced Placement exam for that subject (and score, if you remember it):

Biology _____ Years AP Y / N AP score (if taken) 1 2 3 4 5
Chemistry _____ Years AP Y / N AP score (if taken) 1 2 3 4 5
Physics _____ Years AP Y / N AP score (if taken) 1 2 3 4 5

Please list any Eastern Florida State College science course you have already completed.

Please list any additional science courses you have taken at other institutions.

Please circle the classroom instructional method that you believe is best for you in learning biology.

Lecture Discussion/Seminar Laboratory/Hands-on Demonstration

What are your career goals, if any, right now?

What concerns do you have about taking this course?

Name (only for research, not grades *):
Section: ______________ Class: ______________ Sex: M / F
County in which you attended high school: ____________

*Names are only asked so we can compare individuals' responses over the semester. The survey has no effect on your grade!
**Biology 1 BSCC 1010 – Posttest** This survey is designed to collect information on your previous experience in biology. You can help the teaching staff gain a better sense of your preparation and experience by completing this survey. Your responses on this survey will have no bearing on your grade. However, you will positively affect your own experience in this course by responding thoughtfully and honestly. Thanks for your feedback!

**Terminology:** The following table contains vocabulary taken from the glossary in the back of the text and represents some of the important terms in genetics. For each word, indicate your familiarity with the term in the context of biology and genetics (several have non-scientific meaning as well) on a scale of 1-5 as shown. Remember that we do not expect or assume you to know all—or even any—of these terms prior to the course.

| What is your level of understanding of these terms in the context of biology/genetics? | Very Poor | Poor | Average | Good | Excellent | What is your level of understanding of these terms in the context of biology/genetics | Very Poor | Poor | Average | Good | Excellent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| allele | 1 | 2 | 3 | 4 | 5 | meiosis | 1 | 2 | 3 | 4 | 5 |
| amino acid | 1 | 2 | 3 | 4 | 5 | messenger RNA | 1 | 2 | 3 | 4 | 5 |
| anaphase | 1 | 2 | 3 | 4 | 5 | metaphase | 1 | 2 | 3 | 4 | 5 |
| anticodon | 1 | 2 | 3 | 4 | 5 | non-disjunction | 1 | 2 | 3 | 4 | 5 |
| autosomes | 1 | 2 | 3 | 4 | 5 | nucleus | 1 | 2 | 3 | 4 | 5 |
| bacteriophage | 1 | 2 | 3 | 4 | 5 | Okazaki fragment | 1 | 2 | 3 | 4 | 5 |
| centromere | 1 | 2 | 3 | 4 | 5 | operon | 1 | 2 | 3 | 4 | 5 |
| chiasma | 1 | 2 | 3 | 4 | 5 | pedigree | 1 | 2 | 3 | 4 | 5 |
| chromosome | 1 | 2 | 3 | 4 | 5 | phenotype | 1 | 2 | 3 | 4 | 5 |
| clastron | 1 | 2 | 3 | 4 | 5 | plasmid | 1 | 2 | 3 | 4 | 5 |
| diploid | 1 | 2 | 3 | 4 | 5 | polymerase | 1 | 2 | 3 | 4 | 5 |
| dominance | 1 | 2 | 3 | 4 | 5 | polymerase chain | 1 | 2 | 3 | 4 | 5 |
| electrophoresis | 1 | 2 | 3 | 4 | 5 | recessive | 1 | 2 | 3 | 4 | 5 |
| endonuclease | 1 | 2 | 3 | 4 | 5 | restriction enzyme | 1 | 2 | 3 | 4 | 5 |
| eukaryote | 1 | 2 | 3 | 4 | 5 | reverse transcriptase | 1 | 2 | 3 | 4 | 5 |
| gamete | 1 | 2 | 3 | 4 | 5 | sex-linked | 1 | 2 | 3 | 4 | 5 |
| gene | 1 | 2 | 3 | 4 | 5 | sister chromatids | 1 | 2 | 3 | 4 | 5 |
| genetic code | 1 | 2 | 3 | 4 | 5 | Southern blot | 1 | 2 | 3 | 4 | 5 |
| genome | 1 | 2 | 3 | 4 | 5 | Spooling | 1 | 2 | 3 | 4 | 5 |
| genotype | 1 | 2 | 3 | 4 | 5 | telomere | 1 | 2 | 3 | 4 | 5 |
| Germ cell | 1 | 2 | 3 | 4 | 5 | testcross | 1 | 2 | 3 | 4 | 5 |
| heterozygous | 1 | 2 | 3 | 4 | 5 | transcription | 1 | 2 | 3 | 4 | 5 |
| hybrid | 1 | 2 | 3 | 4 | 5 | translation | 1 | 2 | 3 | 4 | 5 |
| intron | 1 | 2 | 3 | 4 | 5 | X chromosome | 1 | 2 | 3 | 4 | 5 |
| major groove | 1 | 2 | 3 | 4 | 5 | zygote | 1 | 2 | 3 | 4 | 5 |
Now please briefly define the following words or describe their biological significance.

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**Concepts**

*Please answer the following multiple choice and short answer questions. Please provide an answer for each question, even if it is a wild guess. Remember, you are not being graded on this survey.*

1. How does the genetic material in a skin cell compare to the genetic material in a liver cell?
   a. The genetic material is identical in both cells
   b. The genetic material is mostly similar, but differs somewhat
   c. Different amount of genetic material but can't tell how
   d. Different content of genetic matter

2. What does it mean at the molecular level to say that a trait is dominant?

3. You are asked to serve on a jury considering a paternity case. A single mother of a baby is trying to get the father to pay his share of child support. The man she has identified as the baby's father denies the charge. They agree to perform a genetic test; they obtain DNA samples from the child, mother, and accused father and look at the length of DNA fragments resulting from a restriction enzyme digest in a certain region of the human genome. The child shares some of the DNA fragments with the mother but also has several fragments not shown in the mother's sample.

   (c) If the man’s sample contains fragments which match up exactly with those of the mother, what, if anything, could you conclude about the accused man's paternity?

   (d) If the man's sample contains fragments which match up with those of the child not present in the mother, what, if anything, would you conclude about the accused man's paternity?
Background

Which topic(s) in the course do you still not feel confident about?

Which topic(s) in the course that you now understand were most difficult for you to master?

Which topic(s) did you think you understood before the course but now realize that you didn’t?

Which topic(s) were not discussed in enough detail?

Which topic(s) were discussed in too much detail?

Which study strategies were most effective in helping you to learn the material?

Which study strategies were most effective in helping you to perform well on exams?

Did you find that the exams accurately assessed your understanding of the material? Why or why not?

Which parts of the course were most surprising or unexpected for you?

Has the course led you to alter your career goals or concentration? If yes, please explain.

Name (only for research, not grades *): ________________________________
Section: ________________________ Class: ________________ Sex: M / F
County in which you attended high school: __________________________
*Names are only asked so we can compare individuals' responses over the semester. The survey has no effect on your grade!
### Cell Cycle ConceptTests

Please check the number of times the answer was asked for each question below.

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<tr>
<td>c. G2 phase</td>
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<td></td>
</tr>
<tr>
<td>d. M phase</td>
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<td>2. During what phase are chromosomes duplicated?</td>
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<td>a. <strong>G1 phase</strong></td>
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<tr>
<td>b. <strong>S phase</strong></td>
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<td></td>
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<tr>
<td>c. <strong>G2 phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. M phase</td>
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<td></td>
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<tr>
<td>3. During what phase of mitosis are sister chromatids initially separated and moving along the kinetochore microtubules toward opposite ends of the cell?</td>
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<td>a. prophase</td>
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<td>b. metaphase</td>
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<td>c. anaphase</td>
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<td>d. telophase</td>
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**Meiosis ConceptTests**

Please check the number of times the answer was asked for each question below.

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<th>Question</th>
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<td>b) 10</td>
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<td>c) 7</td>
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<td>d) 28</td>
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<td>2. If a cell contains 10 chromosomes after Meiosis I, how many will it contain after Meiosis II?</td>
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<td>a) 20</td>
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<td>c) 5</td>
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<tr>
<td>d) 1</td>
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<td>3. If a cell undergoes Meiosis I, how many cells result?</td>
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<td>a) 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. If a cell undergoes Meiosis, how many cells result after Meiosis II?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mendelian Genetics ConcepTests

Please check the number of times the answer was asked for each question below.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer 1X</th>
<th>Answer 2X</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Flower color in pea plants Purple (A) vs. White (a)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the P generation, a homozygous purple plant is crossed with a white plant. What is the phenotype of the F1 generation?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. All purple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. 50% purple; 50% white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. 75%; white; 25% purple</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. All white</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. 75% purple; 25% white</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| From the results of the last cross, what is the genotype of the F2 Generation? |           |           |
| A. 75% homozygous dominant; 25% homozygous recessive                    |           |           |
| B. 50% homozygous dominant, 25% heterozygous; 25% homozygous recessive |           |           |
| C. 25% homozygous dominant; 50% heterozygous; 25% homozygous recessive  |           |           |
| D. 25% homozygous dominant; 25% heterozygous; 50% homozygous recessive |           |           |

| 3. Determine the genotypes of the following parents:                    |           |           |
| Father blood type A, mother blood type B. All four blood types are represented among the children. |           |           |
| A. Father: AA, Mother: BB                                               |           |           |
| B. Father Ai, Mother Bi                                                |           |           |
| C. Father Ai, Mother BB                                                |           |           |
| D. Father AA, Mother Ai                                                |           |           |

| EPISTASIS: In Labrador retrievers, different coat colors result from variations in the amount, distribution and deposition of melanin. If B codes for coat color, E codes for melanin deposition and D codes for melanin production, what color will dogs with BBEedd genotypes be? |           |           |
| **Key:** B=Black b=chocolate; E = deposit color in fur, e = no deposit; D= melanin production in animal, d= no melanin production. |           |           |
| A. Albino                                                               |           |           |
| B. Black                                                                |           |           |
| C. Yellow                                                               |           |           |
| D. Chocolate                                                            |           |           |
Genetic Disorders ConceptTests

Please check the number of times the answer was asked for each question below.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer 1X</th>
<th>Answer 2X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUTOSOMAL RECESSIVE CROSS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albinism is an autosomal recessive disease in humans. A male and a female, both heterozygous, mate. What chance is there of producing a normal carrier?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. AUTOSOMAL DOMINANT CROSS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huntington's is an autosomal dominant disease in humans. A heterozygous male and a normal female mate. What chance is there of producing an affected child: a carrier: non-carrier?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. X-LINKED RECESSIVE CROSS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In man, color-blindness, an inability to distinguish between red and green, is inherited as a sex-linked character on the X chromosome. It is recessive. If a normal man marries a color-blind woman, where will colorblindness likely be found in the family?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. All the sons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. All the daughters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. 50% sons; 50% daughters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. No one will be colorblind</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. Calico cats are both black and orange. In the species, coat color is x-linked and coded for by multiple alleles: The black and orange alleles are co-dominant, and white is recessive. Which genetic disorder could produce a male calico cat?</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Turners syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Cri-du-chat syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Hemophilia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Klinefelter's syndrome</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B

Institutional Review Board Documents
Florida Institute of Technology

Institutional Review Board Office
Dr. Lisa Steelman, Chair IRB
School of Psychology
(p) 674-8104
lsteelma@fit.edu
http://www.fit.edu/research/committees/irb/index.html

RESEARCH INVOLVING HUMAN SUBJECTS
Exempt Application

This form shall be used if there is minimal risk to human subjects and one or more of the conditions below apply. If there is more than minimal risk associated with the research (none of the conditions below apply) or if the research utilizes a special population (children, prisoners, institutionalized individuals, etc.), please use the full application form found on the IRB website.

You should consult the university's document "Principles, Policy, and Applicability for Research Involving Human Subjects" prior to completion of this form. Copies may be obtained from the Office of Sponsored Programs and on the IRB website.

Name: Holly McKnight
Date: November 8, 2013
Academic Unit: Science Education
Email: mcknightl@easternflorida.edu

Title of Project: The Effect of Using Peer Instruction on State College Students' Achievement in an Introductory Biology Unit in Genetics

☐ 1) Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as:
   a. research on regular and special education instruction strategies, or
   b. research on the effectiveness of or the comparison among instruction techniques, curricula, or classroom management methods.

☐ 2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless:
   a. the subjects can be identified, directly or through identifiers linked to the subjects and
   b. any disclosure of subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

   Note: This exemption does not apply to survey procedures or interviews involving minors.

☐ 3) Research involving the use of educational tests, survey or interview procedures, or observation of public behavior if:
   a. the subjects are elected or appointed public officials or candidates for public office or
   b. the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

☐ 4) Research involving the collection or study of existing data, documents, records, or specimens if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, indirectly or through identifiers linked to the subjects.

☐ 5) Research and demonstration projects that are conducted by or subject to the approval of Department or Agency heads and that are designed to study, evaluate, or otherwise examine:
   a. public benefit or service programs,
   b. procedures for obtaining benefits or services under those programs,
   c. possible changes in or alternatives to those programs or procedures, or
   d. possible changes in methods or levels of payment for benefits or services under those programs.

☐ 6) Taste and food quality evaluation and consumer acceptance studies if:
   a. wholesome foods without additives are consumed or
   b. food is consumed that contains food ingredients found to be safe by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.
1. List the objectives of the proposed project.

Students' conceptual framework on targeted science concepts will be assessed as intact groups from General Biology I, BSCC 1010, a first year biology course. During the treatment, alternative instruction in the form of peer instruction will be used to integrate targeted genetics concepts into students' schema. Conceptual change will be assessed both individually and as separate groups by use of ConcepTests based on Peer Instruction: A User's Manual [Mazur 1997]. The answers will be scored using a computerized voting system in the way of educational clickers to score individual and group responses. These scores will be evaluated to reveal if there was conceptual change in the answers from the first "individual" response to the second "group response". In addition, a pre and posttest will be administered in the form of a genetics survey. It will include a survey designed by Fagen (2003) that address concepts covered in the course in the area of molecular and population genetics. It will also address background information on students in regards to student demographics and science course experience, on the pretest, while the posttest will concentrate on their experience throughout the semester.

2. Describe the research project design/methodology. Discuss how you will conduct your study, and what measurement instruments you are using. If your project will use a questionnaire or structured interview, attach. Please describe your study in enough detail so the IRB can identify what you are doing and why.

The methodology is a quasi-experimental design. Students will be selected by a randomized, one-treatment-control group, pretest/posttest, quasi-experimental design. The students who are selected to participate will attend Eastern Florida State College at the Palm Bay Campus during the Spring and Fall semesters of 2014. Treatment and control groups will be selected each term. Treatment groups will be taught with Peer Instruction while the control group will be taught with a traditional teaching approach. By selecting students in both Fall and Spring semesters, baseline data from previous terms can be used to compare with study results.

To demonstrate group equivalency a pre-test will be given at the beginning of the term to identify all groups are equally matched on the study’s dependent variables. The results of the assessment will be statistically examined to determine similarities in age, gender, ethnicity, and science background.

Two instruments will be used to measure science achievement in this study; ConcepTests as introduced by the Mazur Group and genetics survey by Fagen (2003). The ConcepTests will be given to the treatment group throughout their unit in Genetics. The genetics survey will be given at the beginning of the semester, during Week 1, to confirm group equivalence. It will also be administered at the end of Week 14 as a post-assessment. A brief description of the instruments follows.

The ConcepTests are based on the Mazur Group's Project Galileo. Though there are an abundance of ConcepTests for other science disciplines, however, there is only one ConcepTest question for biology in the area of genetics. There are no other questions in any other area in biology. Additional questions will be made by the researcher. Content validity will be assessed by a team of biology professors at Eastern Florida State College that have been teaching in the field for 20 plus years.

1. How does the genetic material in a skin cell compare to the genetic material in a liver cell?
   a. The genetic material is identical in both cells
   b. The genetic material is mostly similar, but differs somewhat
   c. Different amount of genetic material but can't tell how
   d. Different content of genetic matter

Answer: Each cell in your body (with the exception of sperm and eggs) should have the identical genetic material.

Placed in Public Domain by Adam Fagen, 2000

ConcepTests are given by interspersing presentation of course material with related conceptual questions which probes students' understanding of central concepts being presented. When the question is first asked, students are given one or two minutes to formulate their individual responses. Afterwards students have four minutes to discuss their answers with their group and convince them of their correctness. The instructor moves around to listen to these discussions to hear possible misconceptions that may exist in the classroom. The instructor ends the group discussions by calling for a final polling of answers. These answers may or may have not changed due to group
conversations. ConcepTests provide students with opportunities for conceptual change by allowing students time to reconstruct their ideas about a given concept.

Each ConcepTest has the following general format:

1. Question posed 1 minute
2. Students given time to think 1-2 minutes
3. Students record/report individual answers
4. Neighboring students discuss their answers 2-4 minutes
5. Students record/report revised answers
6. Feedback to teacher: Tally of answers
7. Explanation of correct answer 2+ minutes

The genetics survey pretest/posttest is attached for your review.

3. Describe the characteristics of the subject population, including number, age, sex, and recruitment strategy (attach actual recruitment email text, recruitment flyers etc).

The target population of this study is all State College students in Florida enrolled in General Biology 1. The accessible population is all students at Eastern Florida State College which is located on five campuses between the northernmost campus in Titusville and the southernmost campus in Palm Bay. The samples will be selected from students registered for Biology 1 on the Palm Bay Campus. Eastern Florida State College confers both 2 and 4 year degrees.

A proposed sample of 300 Eastern Florida State College students will participate in this study. The students selected will be enrolled in BSCC 1010, General Biology 1, during the 2014 Spring and Fall semesters. The sample will be taken from the Palm Bay Campus, the southernmost campus in Brevard County.

4. Describe any potential risks to the subjects (physical, psychological, social, legal, etc.) and assess their likelihood and seriousness. Research involving children must carefully assess risks and describe the safeguards in place to minimize these risks.

This research will be conducted in an educational setting to assess instructional strategy effectiveness. There are no known or foreseeable risks to students in this study.

5. Describe the procedures you will use to maintain the confidentiality and privacy of your research subjects and project data.

Students in this study will have complete anonymity. All of their responses will be held in confidence. Only the researchers involved in this study and those responsible for research oversight will have access to any information that could identify student responses. Student names will be numbered code linking a number with a name.

6. Describe your plan for informed consent (attach proposed form).

Informed consent will be given at the beginning of the term before the pretest genetics survey.

7. Discuss the importance of the knowledge that will result from your study and what benefits will accrue to your subjects (if any).

The purpose of this study is to examine the effect of using Peer Instruction on State College students’ achievement in an introductory biology unit in Genetics. There have been many studies by Mazur in the area of physics that address Peer Instruction as an alternative teaching technique to enhance student learning of difficult concepts; however there has been limited research in the area of biology. The proposed study will be
based on Mazur (1991) and his findings of peer instruction in the area of physics and will be applied to the biological sciences. This study provides a method to analyze the potential impact of using Peer Instruction to increase student performance and understanding of genetics concepts.

8. Explain how your proposed study meets criteria for exemption from Institutional Review Board review (as outlined on page 1 of this form).

The research will be conducted in an educational setting to assess the effectiveness of Peer Instruction. There are no ascertained risks to participants. Student's names will remain confidential. If a minor is dual enrolled in the course they will have to have the consent form signed by their parent.
Signature Assurances

I understand Florida Institute of Technology's policy concerning research involving human subjects and I agree:

1. to accept responsibility for the scientific and ethical conduct of this research study,
2. to obtain prior approval from the Institutional Review Board before amending or altering the research protocol or implementing changes in the approved consent form,
3. to immediately report to the IRB any serious adverse reactions and/or unanticipated effects on subjects which may occur as a result of this study,
4. to complete, on request by the IRB, a Continuation Review Form if the study exceeds its estimated duration.

Pl Signature ________________________________ Date 11/19/13

Advisor Assurance: If primary investigator is a student
This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of the study, the necessity for the use of human subjects in the study to the student's academic program, and the competency of the student to conduct the project.

Major Advisor ________________________________ Date 11/19/2013
Major Advisor (print) __________________________ Date 11/19/2013

Academic Unit Head: It is the PI's responsibility to obtain this signature
This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of this study and the competency of the investigator(s) to conduct the study.

Academic Unit Head ________________________________ Date 11/19/2013

FOR IRB USE ONLY

IRB Approval ________________________________ Date 11/28/13
Name ________________________________
IRB # ________________________________
Research Informed Consent

Purpose:
A research study is being conducted to examine instructional strategies for Biology 1 (BSCC 1010) at Eastern Florida State College. The purpose of this study is to improve how biology is taught and data will be collected on unitization of instruction of the course.

Procedures:
Participation in this study will involve filling out a survey at the beginning and the end of the course. You will be assessed on your prior knowledge of genetics and background information on the initial survey. The post survey will reassess your knowledge of genetics and ask about your experience during the course to the instructional practices.

Risks and Benefits:
This research will be conducted in an educational setting to assess instructional strategy effectiveness. There are no known or foreseeable risks to students in this study.

Confidentiality:
All of your responses will be held in confidence. Only the researchers involved in this study and those responsible for research oversight will have access to any information that could identify your responses. Your name will be numbered code linking your number with your name. When we publish any results from this study we will do so in a way that does not identify you unless we get your specific permission to do so. We may also share the data with other researchers so that they can check the accuracy of our conclusions but will only do so if we are confident that your confidentiality is protected.

Voluntary Participation:
Participation in this study is completely voluntary. You are free to decline to participate, to end participation at any time for any reason, or to refuse to answer any individual question without penalty. This survey has no effect on your grade in this course. If you choose not to be involved in the study it will have no bearing on your grade.

Questions:
If you have any questions about this study, you may contact the investigator, Holly McKnight, 433-5355.

Agreement to Participate:
I have read the above information, have had the opportunity to have any questions about this study answered and agree to participate in this study.

(printed name) (date)

(signature)

11/15/2013
Signature Assurances

I understand Florida Institute of Technology’s policy concerning research involving human subjects and I agree:

1. to accept responsibility for the scientific and ethical conduct of this research study,
2. to obtain prior approval from the Institutional Review Board before amending or altering the research protocol or implementing changes in the approved consent form,
3. to immediately report to the IRB any serious adverse reactions and/or unanticipated effects on subjects which may occur as a result of this study,
4. to complete, on request by the IRB, a Continuation Review Form if the study exceeds its estimated duration.

PI Signature

Date: Nov 19, 2013

Advisor Assurance: If primary investigator is a student

This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of the study, the necessity for the use of human subjects in the study to the student's academic program, and the competency of the student to conduct the project.

Major Advisor

Date: Nov 19, 2013

Major Advisor (print)

Academic Unit Head: It is the PI's responsibility to obtain this signature

This is to certify that I have reviewed this research protocol and that I attest to the scientific merit of this study and the competency of the investigator(s) to conduct the study.

Academic Unit Head

Date: Nov 19, 2013

FOR IRB USE ONLY

IRB Approval

Name

IRB #

Date

EFSC Institutional Review Board
Dear Ms. McKnight:

Your research proposal was reviewed and approved by the IRB Chairperson. Per federal regulations, 45 CFR 46.110 [Expedited Review] and CFR 46.101(b) [Exempt], your proposed study has been determined to involve no more than minimal risk for human subjects and is exempt. Federal regulations define minimal risk to mean that the probability and magnitude of harm are no more than would be expected in the daily life of a normal, healthy person. Your proposed study does not allow subjects to be identified, the research will be conducted in an educational setting, involving normal educational practices and will include the use of survey procedures; this supports the Exempt status.

Procedural changes or amendments must be reported to the IRB, and no changes may be made without IRB approval except to eliminate apparent immediate hazards.

This submission is approved for one year from the above date. If data collection continues past this date, a request for Continuing Review must be made.
APPENDIX C

Program Related Material
BSCE 1010
Fall 2014 Term

GENERAL BIOLOGY 1 COURSE SYLLABUS

Instructor

Contact Information
Email:

And Office Hours
Office Hours:
You may also send messages via the Canvas course site.
For computer access, go to the Computer Lab in 2-235.
Direct computer problems to the FFSC Helpdesk (321.493.7600)

Course Description
An introduction to principles of biology to include a study of: cell structure, function and
reproduction; inheritance, development, metabolism, photosynthesis, evolution, and DNA
technology. 2 1/2 hours of lecture and 1 1/2 hours of lab per week.* This course uses the
Canvas site for announcements, grades, and more. Please check the site before each class.

Course Objectives & Competencies
To promote and develop an appreciation and respect for the biological world; to develop an
awareness of the relationships existing between the biological and physical worlds and their
interrelationships; to understand the position and role of man as related to his environment and
way of life; to understand the major basic biological principles; to develop skills of observation,
perception and reasoning; to promote skills and knowledge that will better enable individuals to
effectively participate in events that have bearing on their own lives.

Competencies:
1. Integrate fundamental chemical principles to biological systems.
2. Interpret structural differences in biomolecules.
3. Relate cell structures to cell physiology.
4. Summarize relationships between cell biochemistry and catabolism of biomolecules.
5. Interpret anabolic pathways, with focus on stages of photosynthesis.
6. Differentiate between various modes of cell division.
7. Analyze outcomes of genetic combinations.
8. Relate cell physiology to the processes of gene expression.
9. Determine relationships between groups of living organisms.
10. Apply principles of population genetics to case studies in evolution.
11. Develop philosophy of life that includes considerations of the biological world.
12. Utilize proper safety procedures applicable to lab ware and biological materials.

Required Material
Textbook: Campbell Biology      Author: Reece, Jane B., et al.
Publisher: Benjamin Cummings  Edition: 10th  Date: 2014

WITHDRAWAL POLICY

Students may withdraw without academic penalty from any course by the established deadline (Oct. 30, 2014). This will result in a grade of 'W' for the course and will not count against the student's GPA. Students will be permitted a maximum of two withdrawals per course. Upon the 3rd attempt, the students WILL NOT be permitted to withdraw and will receive an earned grade for that course.

ABSENCES, MAKE-UPS, and LATE ASSIGNMENTS

- The student is expected to attend each class and is responsible for all material covered or assigned during class. Regular attendance is required by college regulations and is essential for academic success. Any student who misses 15% of the scheduled classes (10.5 hours) may be dropped from the course.

- A missed quiz or exam may only be made up for valid, documented excuses. You must contact me within 48 hours of missing a quiz or exam and have valid documentation to excuse your absence and qualify for a makeup. Otherwise, a missed quiz or exam will count as zero. The makeup quiz or exam will be in a different (most likely essay) format and will be administered by the EFSC Learning Lab (PB 1-234, ph: 321-435-5252).

- If you miss your regularly scheduled lab, you will receive a grade of 0 for that lab, with the exception of online or take-home labs. One missed lab may be made up independently by completing Lab 17 in your lab manual and turning it in prior to taking your final exam. Additional missed labs cannot be made up. There is no makeup on the lab practical.

- Assignments must be turned in at the beginning of the class in which they are due, in order to receive full credit. A late assignment will receive a 10% deduction if turned in within 24 hours of the due date/time and a 20% deduction if turned in within 48 hours of the due date/time. No credit will be given if 48 hours have passed. If a student has a valid, documented excuse for being absent on the original turn-in date, the assignment will be due at the beginning of the next class meeting.

EFSC RELIGIOUS OBSERVANCE POLICY

When observance of religious holidays interferes with class attendance or work, a student is to notify the instructor in writing within the first week of class. Students are accountable for material covered during their absence. The instructor will provide alternative arrangements for the student to complete any missed work. Students are expected to complete work without undue delay. Students who believe they have been unreasonably denied accommodation due to religious beliefs or practices have the right to seek redress through the student appeal procedure.

DISABILITIES

Students with documented disabilities who desire to receive services including special testing conditions, or who need specific accommodations, should register with the Office for Students with Disabilities. The office keeps everything confidential and services received are not recorded on one's transcript or diploma. Services may not be received without this registration.

ACADEMIC HONESTY

Your participation in this course serves as your agreement to abide by accepted BCC guidelines for academic honesty. Academic dishonesty is defined as representing another person's work as your own or active participation in this type of action on the part of another person. This may result in expulsion from this course with a failing grade. Although study groups are encouraged, allowing other students to copy your answers for any graded assignment is considered cheating. Any use of cell phones is prohibited during testing. If your cell phone is out and/or visible during an exam, quiz, or practical, you may be dismissed from class and given a zero on that assignment.
CLASS ETIQUETTE

- Be on time and stay until you are dismissed. If you must leave early, notify the instructor and sit by a door.
- Pay attention in class, even to videos. You may be tested on material in them.
- Don’t distract other students by talking while the instructor is talking, talking out of turn, and/or asking irrelevant questions. Wait until the instructor calls for questions rather than interrupting in the middle of a concept. Chances are that your questions will be answered in the next sentence.
- For personal concerns, please see or email the instructor during office hours, not before class. You may email your questions/concerns at any time.
- Please remember that this is a college classroom, and you are expected to function as an adult. Anything less will not be tolerated.
- Food and drink are not allowed in the classrooms.
- Turn off cell phones when you enter any classroom. Use of cell phones is prohibited during class or test taking. Texting during lectures is both distracting and disrespectful.

TIPS FOR SUCCESS

- **Before Class**
  - Read the Canvas companion Site! Make sure you navigate through ALL the menu items.
  - Keep track of important dates! See Canvas Calendar and Mastering Biology Calendar for assignments.
  - Check Canvas at least four times weekly for important announcements.
  - Read the textbook—before class, after class, or both
  - Learn the vocabulary—use the crossword puzzles on ANGEL or make flash cards—before the lecture

- **During Class**
  - Be early or on time for class to start. Have your lecture outlines printed and ready before coming to class.
  - Be prepared to answer review questions from Canvas if called upon in class.
  - Bring a Smartphone, Tablet, or Computer to use in class for Learning Catalytics.

- **After Class**
  - Study a little every day. Expect 2 hours study time for every hour in class (~8 hours/week!)
  - Work the Homework problems on Mastering Biology website.
  - Complete all Lab Quizzes posted in Canvas and Pre-Lecture Quizzes in Mastering Biology.
  - Form study groups
  - Complete all the assignments on the **Campbell Website**: [www.masteringbiology.com](http://www.masteringbiology.com)
  - Ask for help! Come to office hours.

Common Problems

- Not enough study time or not studying effectively
- Not testing your knowledge before taking a test
- Not reading the test carefully
- Poor attendance
- Cramming the night before a test
- Test anxiety
<table>
<thead>
<tr>
<th>Week Of</th>
<th>Lecture Topic</th>
<th>Laboratory Topic</th>
<th>Lab #</th>
</tr>
</thead>
<tbody>
<tr>
<td>08/18/13</td>
<td>Biochemistry</td>
<td>Lab Safety/*Microscope Tutorial</td>
<td>1</td>
</tr>
<tr>
<td>08/25/13</td>
<td>Biochemistry</td>
<td>Measurement (Labs run T-M)</td>
<td>2</td>
</tr>
<tr>
<td>09/01/13</td>
<td>Biochemistry</td>
<td>Microscopy</td>
<td>3</td>
</tr>
<tr>
<td>09/08/13</td>
<td>Cell Membranes/Holiday</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>09/15/13</td>
<td>Cell Structure</td>
<td>Dialysis</td>
<td>5</td>
</tr>
<tr>
<td>09/22/13</td>
<td>Energy Metabolism</td>
<td>Enzyme Activity</td>
<td>6</td>
</tr>
<tr>
<td>09/29/13</td>
<td>Photosynthesis</td>
<td>Photosynthesis</td>
<td>7</td>
</tr>
<tr>
<td>10/06/13</td>
<td>Respiration</td>
<td>Respiration</td>
<td>8</td>
</tr>
<tr>
<td>10/13/13</td>
<td>Mitosis/Mitosis</td>
<td>Mitosis</td>
<td>9</td>
</tr>
<tr>
<td>10/10/13</td>
<td>Genetics</td>
<td>*Meiosis</td>
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<tr>
<td>10/27/13</td>
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<td>11/03/13</td>
<td>DNA</td>
<td>Lab Review/*Karotvoina</td>
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<td>11/10/13</td>
<td>Proteins &amp; Gene Control</td>
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<td>11/17/13</td>
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<tr>
<td>11/24/13</td>
<td>Evolution/Classification</td>
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<td>15-17</td>
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<tr>
<td>12/01/13</td>
<td>Environmental Biology - cancer</td>
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<td>Optional Labs</td>
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Use this section to keep track of your **RAW SCORES** (not percentages) for tests and labs:

<table>
<thead>
<tr>
<th>Number</th>
<th>Topic</th>
<th>Points Achieved</th>
<th>Points Possible</th>
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<tbody>
<tr>
<td>Exam 1</td>
<td>Chapter 2-5</td>
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<td>Exam 2</td>
<td>Chapter 6-8</td>
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<td>Exam 3</td>
<td>Chapter 9-10</td>
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<td>Exam 4</td>
<td>Chapter 12-15</td>
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<td>Exam 5</td>
<td>Chapter 16 - 18 &amp; 20</td>
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<td>Finals</td>
<td>Chapter 22-24, 26</td>
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<td>Lab Inventory Quiz</td>
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<tr>
<td>Lab 1</td>
<td>*Microscope Tutorial (2-235)</td>
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<tr>
<td>Lab 2</td>
<td>Scientific Measurement</td>
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<td>Lab 3</td>
<td>Microscopy</td>
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<td>Lab 4</td>
<td>Diffusion</td>
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<td>Lab 5</td>
<td>Dialysis</td>
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<td>Lab 6</td>
<td>Enzyme Activity</td>
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<td>Lab 7</td>
<td>Photosynthesis</td>
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<td>Lab 8</td>
<td>Respiration</td>
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<td>Lab 9</td>
<td>Mitosis</td>
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<tr>
<td>Lab 10</td>
<td>*Meiosis (2-235)</td>
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<tr>
<td>Lab 11</td>
<td>Genetics</td>
<td>10</td>
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<tr>
<td>Lab 12</td>
<td>*Karotvoina (on-line)</td>
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<tr>
<td>Lab 13</td>
<td>Genetic Engineering</td>
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<td>Lab 14</td>
<td>*Natural Selection (2-235)</td>
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<tr>
<td>Lab 15</td>
<td>Classification (lab manual)</td>
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<td>Lab 16</td>
<td>Environmental Biology</td>
<td>10</td>
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<tr>
<td>Lab Technique</td>
<td>Set up/clean up</td>
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<tr>
<td>Lab Practical</td>
<td>Labs 1-12</td>
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Peer Instruction Study Fall 2014 BSCC 1010

(1) Introduction to study
The purpose of this study is to examine the effects of Peer Instruction (PI).
- Students will discuss biological concepts in the area of genetics among their peers during class time.
- These conceptual questions are delivered to the student in the form of ConcepTests, conceptual questions designed to uncover students’ misconceptions in the material.
- Students first answer a question projected from the computer to an overhead screen on their own (NO talking, notes, book, etc).
- Depending on the percentage of students that answer correctly, students then discussed their answers with their peers (PI).
- These discussions allowed students to uncover their misunderstandings in the material.
- Class time is given to students to explore their understanding of the material by participating in guided scientific discussion.

(2) Visual diagram of ConcepTests administration with respect to time and placement in the lesson;

Think, Poll, Discuss, Re-poll, Explain.
(3) Clickers are kept in Room 2-331 in the locked cabinet.

(4) Students must retain the same clicker for the extent of the study;

(5) ConcepTests are in Analyzer on your desktop.
    a. Data stores difference between the first and second time students click. Please let me know the number of times you asked question (once or twice) on checksheet.
    b. I will need all data for each student to be stored on the same clicker.

(6) Students should not be able to see the screen. Freeze screen.

(7) Clicker directions are on the next page.

(8) Copies post-assessments will be given after this unit.
### Peer Instruction Schedule:

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Day</th>
<th>Section</th>
<th>Time</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>At</td>
<td>MW</td>
<td>06B</td>
<td>8:00</td>
<td>2-339</td>
</tr>
<tr>
<td>Bt</td>
<td>TTh</td>
<td>14B</td>
<td>1:40</td>
<td>3-339</td>
</tr>
<tr>
<td>Ct</td>
<td>TTh</td>
<td>10</td>
<td>12:15</td>
<td>2-331</td>
</tr>
<tr>
<td>Dt</td>
<td>TTh</td>
<td>11B</td>
<td>1:30</td>
<td>2-338C</td>
</tr>
<tr>
<td>Et</td>
<td>TTh</td>
<td>71B</td>
<td>6:00</td>
<td>2-352B</td>
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</table>

### Control Schedule

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Day</th>
<th>Section</th>
<th>Time</th>
<th>Room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac</td>
<td>Th</td>
<td>12B</td>
<td>1:40</td>
<td>2-339</td>
</tr>
<tr>
<td>Bc</td>
<td>MW</td>
<td>05B</td>
<td>12:15</td>
<td>2-331</td>
</tr>
<tr>
<td>Cc</td>
<td>MW</td>
<td>02B</td>
<td>10:50</td>
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<tr>
<td>Dc</td>
<td>MW</td>
<td>03B</td>
<td>12:15</td>
<td>2-338C</td>
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<tr>
<td>Ec</td>
<td>TTh</td>
<td>01B</td>
<td>8:00</td>
<td>2-352B</td>
</tr>
</tbody>
</table>
Clicker Directions:

*Be sure to plug the USB hardware into the computer before starting.*

1. Click on **ACQUISITION**
2. Click on your Class Section.
3. Click on **SLIDES** at the top.
4. Click **OPEN SLIDES**
5. Click on the Unit (cell cycle, meiosis, etc.)
6. Once the question is open “**FREEZE**” your screen.
7. Click **START**
8. Have class discuss answers after time runs out IF under 80% get question right.
9. Click **START** again.

10. If they all buzz in before the time runs out click **STOP**.

11. Unfreeze screen to reveal % correct. If under 80% revisit concept, otherwise move on.

12. Click to next question and then “**FREEZE**” the screen.

13. Repeat directions 6-12.