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Peer Led Team Learning in Introductory Biology: Effects on Critical Thinking Skills

Julia J. Snyder
Syracuse University

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ABSTRACT

This study evaluated the potential effects of the Peer-Led Team Learning (PLTL) instructional model on undergraduate, biology peer leaders' critical thinking skills. This investigation also explored peer leaders' perceptions of their critical thinking skills. A quasi-experimental pre-test/post-test with control group design was used to determine critical thinking gains in PLTL/non-PLTL groups. Critical thinking was assessed using the California Critical Thinking Skills Test (CCTST) among participants who had previously completed and been successful in the second semester of a two-semester introductory biology course sequence. Qualitative data from open-ended questionnaires confirmed that factors thought to improve critical thinking skills such as interaction with peers, problem solving, and discussion were perceived by participants to have an impact on critical thinking gains. However, no significant quantitative differences in peer leaders' critical thinking skills were found between pre- and post-treatment CCTST measurements nor between experimental and control groups. Additionally, students led by peer leaders attained significantly higher exam and final course grades in introductory biology than similar students not participating in PLTL. Finally, among introductory biology students who opted not to enroll in the associated lab course, those who participated in PLTL averaged more than a letter grade higher than those who did not, and this difference was statistically significant.

PEER LED TEAM LEARNING IN INTRODUCTORY BIOLOGY:
EFFECTS ON CRITICAL THINKING SKILLS

by

Julia J. Snyder

B.S., SUNY Environmental Science and Forestry, 1999
M.S., Syracuse University, 2001
Ph.D., Syracuse University, 2012

Dissertation
Submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in *College Science Teaching*.

Syracuse University
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DEDICATION

I dedicate this work to my family; those who are no longer with me, as well as those who have been there to support me through this entire process. Words cannot express my gratitude and love for each and every one of you.

To my parents, Charles and Marcia Seymour, who have taught me what it means to work hard and endure, and whose unwavering love, support, and belief in me has made me who I am today.

To my children, Isabelle and Bradley, who could have been my reason to quit, but became my reason to never give up.

To my precious daughter, Emma, who not only patiently tolerated her distracted mom for many months, but offered constant encouragement and excitement about me “finishing my book”.

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CHAPTER 1: INTRODUCTION

Overview

This introduction discusses a student-centered instructional model known as Peer-Led Team Learning (PLTL) and research on the effectiveness of the approach on both students and peer leaders involved in the program. Based on prior studies and relevant theory, research questions developed in the interest of guiding a proposed effort to address gaps in the current literature around the effectiveness of the PLTL training and leadership experience on critical thinking are presented.

Statement of the Problem

Over the past two decades, leading science and science education organizations (American Association for the Advancement of Science, 1989; NRC, 1999; NSF, 1996) have emphasized the importance of group activity to improve students' conceptual understanding and more recently, productive engagement in science (NRC, 2010). This has led to a call for a paradigm shift from traditional, instructor-centered classrooms to student-centered classrooms; providing students an opportunity to be actively engaged in their learning. Nevertheless, at large universities, undergraduate students are often enrolled in large lectures in which students have few opportunities to engage in small group activities. As emphasized by the Science College Board Standards for College Success (2009), group activities for students studying science are of particular importance in providing an opportunity for engagement in science.

Peer-Led Team Learning (PLTL) is one pedagogical approach to providing small group instruction without abandoning the large lecture component of undergraduate courses that has become so deeply entrenched in university systems. The PLTL approach was developed in the early 1990's (Woodward, Gosser and Weiner, 1993) and implemented in undergraduate chemistry courses to allow students to work in problem-solving teams (Gosser, Roth, Gafney, Kampmeier, Strozak, Varma-Nelson, Radel, and Weiner, 1996). Since its conception, PLTL has been introduced into other undergraduate science courses, including organic chemistry, biology, and anatomy and physiology (Hewlett, 2004; Tenney and Houck, 2003; Wamser, 2006). In the PLTL model, students work in small groups of six to eight students led by an undergraduate peer who has previously taken and been successful in the course. Peer leaders work collaboratively with the course instructor to facilitate small group problem-solving after being trained in learning theory, pedagogical methods, and the conceptual content of the course (Gosser and Roth, 1998). Leaders are not experts in the content, nor are they expected to provide answers to the students in their workshop groups, rather they guide and mentor students to develop their own understanding of concepts.

Since the introduction of PLTL, many studies have documented the effectiveness of the PLTL model. Research has focused primarily on the academic benefits to the students who have participated in the PLTL workshops. Studies have shown improvement in students' performance, attitudes, retention in the course (Gafney, 2001a; Hockings, DeAngelis, and Frey, 2008; Lyle and Robinson, 2003; Tenney and Houck, 2003; Tien, Roth and Kampmeier, 2002; Wamser, 2006) conceptual reasoning (Peteroy-Kelly, 2007), and critical thinking skills (Quitadamo, Brahler, and Crouch, 2009), yet little attention has been given to the academic benefits for the peer leaders.

Of the studies that have examined the effects of PLTL on peer leaders of the workshops, only two have focused on the benefits reported by leaders during their leadership experience (Johnson and Loui, 2009; Tenney and Houck, 2004). Through journal entries and survey responses, peer leaders reported benefits such as increased content knowledge, improved communication skills, and increased interest in teaching. In contrast, other studies documented evidence of peer leaders' benefits based on surveys, focus groups, and individual interviews conducted years after college and the leadership experience had been completed (Gafney and Varma-Nelson, 2002; Gafney and Varma-Nelson, 2007; Micari, Streitwieser and Light, 2006). The results of these studies confirmed similar benefits such as reinforcement of the leaders' prior learning, greater confidence, and improved team-related skills. Peer leader participants in a study by Blake (2001) reported perceived gains in their content knowledge. Such gains were confirmed via quantitative analysis of a content quiz given pre- and post-leadership experience which revealed a significant improvement in content knowledge.

Of the few studies that reported on the benefits to peer leaders of the PLTL workshops, most relied only on anecdotal evidence, student self-report (Gafney and Varma-Nelson, 2002; Gafney and Varma-Nelson, 2007; Johnson and Loui, 2009; Tenney and Houck, 2004), or superficial analysis of content gains (Blake, 2001). Whether or not the PLTL training and leadership experience can improve critical thinking in the leaders, as research has shown for the students participating in the workshops (Quitadamo, Brahler, and Crouch, 2009), has yet to be explored.

Theoretical Framework

Although critical thinking is not a new concept, its complex nature has made it difficult for both researchers and practitioners to conceptualize. There is not one definitive definition or theory of critical thinking in the literature. Within critical thinking theory, there are bases in both philosophy and psychology. While philosophical views are based largely on logic and reasoning, psychological views rely on research on cognition and development, as well as theories of intelligence (Reed, 1998; Sternberg, 1985).

From a more philosophical standpoint, critical thinking requires the ability and disposition to make context-specific evaluations and judgments of beliefs (Ennis, 1993; Paul, 1990). Disposition is characterized as the consistent internal motivation to engage problems and make decisions by using critical thinking (Facione, 2000). Psychology based-theories of critical thinking, on the other hand, reflect mastery of skills such as interpreting, predicting, analyzing, and evaluating that can be generalized between contexts (Abrami, Bernard, Borokhovski, Wade, Surkes, Tamim, and Zhang, 2008). There are, however, aspects of agreement between philosophical and psychological conceptualizations. This overlap has important implications for the development of instructional programs to develop critical thinking (McMillan, 1987).

Without a clear conceptualization of critical thinking, it has been difficult for researchers and practitioners to establish appropriate instructional interventions and instruments to appropriately assess critical thinking. Research on the most effective instructional strategies for enhancing students' critical thinking has been inconclusive (McMillan, 1987).

In the interest of educational instruction and assessment, an American Philosophical Association Delphi panel of 46 experts attempted to come to a consensus on critical thinking theory (Facione, 1990a). Of the experts, about half were affiliated with philosophy, while the other half were affiliated with education, social science, or physical science. Based on their report, the Delphi Report, the following consensus statement was determined:

> We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon

> which that judgment is based. Critical thinking is essential as a tool of inquiry. As such, critical thinking is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, critical thinking is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal. It combines developing critical thinking skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society.

Within this statement, both skills and dispositions were associated with critical thinking, providing a framework for instructional interventions and assessment of critical thinking.

Within current critical thinking theory, there are several approaches to teaching critical thinking skills. While some involve explicit instruction of critical thinking separately or within content specific courses (Bangert-Drowns and Bankert, 1990), other approaches focus on creating a classroom environment conducive to fostering critical thinking skills through discussion, cooperative learning, writing, and questioning (Cooper, 1995; King, 1995; McDade, 1995; Wade, 1995).

Regardless of the approach to teaching critical thinking, the literature reveals several classroom activities that have been shown to enhance critical thinking, including faculty and peer interaction (Gellin, 2003; Ory and Braskamp, 1988; Pascarella and Terenzini, 1991; Smith 1977, 1981), writing tasks and class discussions (Tsui, 2002), and problem-based learning activities (Tiwari, Lai, So, and Yuen, 2006).

Because the peer-led team learning leadership model provides an active learning classroom environment that incorporates collaboration amongst faculty and peers through writing tasks and discussion during problem-solving sessions, an environment conducive to critical thinking is established. On this basis, critical thinking skills of peer leaders should improve as a result of the PLTL instructional model.

The PLTL model has its basis in constructivism with the idea that providing students with opportunities to engage in active learning will help them to construct their own personal meaning and understanding (Gosser, Cracolice, Kampmeier, Roth, Strozak, and Varma-Nelson, 2001). Beyond the broad constructivist foundation, PLTL specifically focuses on the social aspects of learning as indicated by Vygotsky (1978). According to his argument that peers may be more effective facilitators of learning than superiors, Vygotsky describes how learning is a social process and that there is a gap between how much a student can learn alone and how much they can learn through working with peers. This gap, known as the zone of proximal development (ZPD), refers to "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978). PLTL allows students to work with a peer leader who is closer to their own ZPD than a course instructor and provides the opportunity for students to work with a peer team on challenging problems that they cannot easily solve on their own. The peer leader provides more course structure and content knowledge than current students and is capable of facilitating participation and peer interaction among the other students.

While the PLTL approach has similarities to cooperative learning models (Johnson and Johnson, 1999) and other student-assisted learning models such as supplemental instruction (Arendale, 1994), it is unique in that the peer-led workshop is integrated within the existing structure of the course by a collaborative effort of the instructor, learning specialist, and peer leader. Weekly workshop groups work together to solve problems carefully structured by the instructor to help students build conceptual understanding. Answer keys are not provided; rather the process of actively finding and evaluating answers by the students in a supportive environment is emphasized.

With this social constructivist basis, PLTL provides a mechanism for enhancing critical thinking skills of undergraduate peer leaders in biology through the use of appropriate instructional interventions based on current critical thinking theory.

Purpose of the Study

The purpose of this study was to contribute to the body of literature on the potential benefits of PLTL to the peer leaders by exploring what influence the training and leadership experience may have on peer leaders' critical thinking skills in the context of an Introductory Biology course at a private, research university in the Northeastern United States. Based on the role of the peer leader and influences thought to improve critical thinking skills, the working premise of this study was that participating as a PLTL peer leader should promote critical thinking gains.

Importance of the Study

Research can and should assist faculty in their efforts to improve the critical thinking skills of students, however, little knowledge on effective pedagogy comes from research on critical thinking (Tsui, 2002). Despite the promotion of critical thinking skills as a goal of colleges and universities (National Education Goals Panel, 1995; Terenzini, Springer, Pascarella, and Nora, 1995; Tsui, 1999), some researchers have found both freshmen and seniors exhibit poor critical thinking skills (Keeley, 1992). More recently, findings based on transcripts, surveys, and results on the Collegiate Learning Assessment, a standardized test that gauges students' critical thinking, analytical reasoning, and writing skills, showed that after two years of college nearly half of the nation's undergraduates showed almost no gains in learning (Arum and Roksa, 2011; as cited by Marklein, 2011).

A study of the effect of PLTL on critical thinking skills of peer leaders in an undergraduate course is important to institutions of higher education and educators who strive to achieve the goal of helping students develop the ability to think critically (Bok, 2006; Gellin, 2003; McMillan, 1987). Unlike content knowledge that tends to lessen over time, critical thinking skills are lifelong skills that can be used in any profession. Even if content is not forgotten, it may become dated in many occupational or professional fields (Terenzini, Springer, Pascarella, and Nora; 1995). Production of critical thinkers, however, is important to producing active members of the community, as well as society at large (ten Dam and Volman, 2004; Tsui, 1999).

In addition, students seeking admission to graduate, medical, or other professional schools, may also benefit from a pedagogical model of teaching and learning that can influence critical thinking skills in a positive manner (Ennis, 1993). Finally, students who have improved critical thinking skills and the disposition to use those skills, combined with good communication and teamwork skills, are likely to be successful in the workplace following their college experience (Facione, Facione, and Winterhalter, 2011; Facione, 2000; Tsui, 1999).

Definitions

The following terms are defined as follows for use in this study:

Peer-Led Team Learning (PLTL): An instructional model that provides small group instruction supplemental to lecture or other components of undergraduate courses. An undergraduate peer leader who has previously taken and been successful in the course works collaboratively with the course instructor and a learning specialist to facilitate a small group of six to eight students in collaborative, problem solving sessions.

Critical Thinking (CT): The conceptualization of the American Philosophical Association (APA); purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. Critical thinking is essential as a tool of inquiry. As such, critical thinking is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, critical thinking is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal. It combines developing critical thinking skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society (Facione, 1990a).

Zone of Proximal Development (ZPD): The gap between how much students can learn alone and the level of potential learning that can be achieved through problem solving in collaboration with more capable peers.

California Critical Thinking Skills Test (CCTST): A valid and reliable, standardized, college level test intended to measure critical thinking skills, as defined by the APA conceptualization, of undergraduate students.

Biology 123: The second course in a sequence of Introductory Biology comprising a survey of major biological concepts ranging from the molecular level to global ecology. Units within the course include biodiversity, plant structure and function, human and comparative animal anatomy and function, ecology, and evolution, which is the central unifying concept of biology and the framework around which the understanding of other concepts in the course is constructed (Wiles, 2011a).

Biology 200: A special topics course offered to undergraduate students who have completed the first semester of introductory biology and are interested in careers in science. Teaching assistants in the biology department offer sections of the course with topics of particular interest to them (Wiles, 2011b).

Insight Assessment: Founded in 1986; provides the California Critical Thinking Skills Test instrument to measure critical thinking skills based on the APA Delphi Panel of Experts definition of critical thinking.

Blackboard (Bb): An online, educational tool used by many colleges and universities to support teaching and learning; faculty provide online resources for students to access.

Research Questions

This study addressed the following questions:

1. Does the PLTL training and leadership experience in biology influence the critical thinking skills of undergraduate peer leaders?

   Sub-Question: Does the PLTL training and leadership experience in biology influence any particular critical thinking skill tested by the CCTST (analysis and interpretation, evaluation and explanation, inference, deductive reasoning or inductive reasoning) more than another?

   Sub-Question: Does peer leader perception of critical thinking correspond to actual CCTST results?

2. What differences in critical thinking skills, if any, exist, between student leaders in the PLTL instructional program and similar students without the PLTL training and leadership experience?

   Sub-Question: How does peer leader perception of critical thinking compare to control group participants' perception of critical thinking?

3. Does the PLTL training and leadership experience in biology influence critical thinking skills of undergraduate peer leaders, controlling for the effects of demographic variables?

   Sub-Question: Which variables have the greatest impact on critical thinking gains?

Delimitations

This study confined itself to undergraduate students who attended a private, four-year, research university in the Northeastern United States. Participation as a peer leader in this study was delimited to students who had previously taken the Biology 123 course and received an overall course grade of B or higher. Students who had not previously taken the Biology 123 course or had previously taken the Biology 123 course and received an overall course grade below a B were excluded from the study.

Participation in the treatment group was delimited to students who had previously taken the Biology 123 course and received an overall course grade of B or higher, as well as were enrolled in Biology 200: Peer-Led Team Learning-A Leadership Experience. Participants who were not enrolled in Biology 200: Peer-Led Team Learning-A Leadership Experience became part of the control group for the study.

Critical thinking skills of undergraduate peer leaders and non-peer leaders were considered in this study. Other variables such as critical thinking dispositions, content knowledge gains, and increased communication of peer leaders and non-peer leaders were not considered in this study.

Critical thinking skills of undergraduate peer leaders and non-peer leaders were measured with the California Critical Thinking Skills Test (CCTST). The CCTST was not a valid and reliable instrument to test any variable other than critical thinking skills. Only tests in which there were responses to at least 60% of the items on the CCTST were scored by Insight Assessment and included in data analyses of critical thinking skills.

Limitations

The sampling procedures used for this study decreased the generalizability of the findings. Results were not generalizable to all undergraduate students in private, research universities, public universities, or two-year colleges.

Seventy five students who had previously taken Biology 123 and received an A or B in the course participated in the CCTST pre-test; 37 participants constituted the treatment group, and 38 participants constituted the control group. While all 37 participants in the treatment group participated in the CCTST post-test, only 17 of the control group participants completed the CCTST post-test. The overall sample size of the study from pre-test to post-test, 54 participants, is relatively small; therefore, results are not likely generalizable to a larger population of undergraduate students.

This study was limited by the willingness of the participants to complete both the CCTST pre-test and post-test. Without completion of the post-test, participants' pre-test data could not be included in the sample. If participants did complete both tests, the study was limited by the willingness of the participants to complete the pre-test and the post-test to the best of their ability and to answer survey questions honestly. Although the CCTST was an appropriate test of critical thinking skills for this study, some participants may not have put forth the effort required to achieve a high score on the test, rather they may have put forth minimal effort to be entered for a gift card drawing.

The post-test was offered to the participants in the study during the last week of the Spring 2011 semester. With that being a very busy time for many undergraduate students, very few participants from the control group returned to take the post-test. Without enough participants in the control group to make comparisons between groups, test administration procedures were switched during the study. While all of the treatment group participants took the paper and pencil post-test, the majority of the control group participants took the online version of the CCTST post-test. Although the online version of the test was the same, and the same amount of time was allotted for the test, online participants were not under the supervision of a proctor like those participants who took the paper and pencil version. Online participants were also unable to take the critical thinking questionnaire given to all participants who took the paper and pencil post-test.

Another limitation of the study includes the high degree of variance possible in the PLTL workshops. There were 37 peer leaders, each leading their own student workshops for twelve weeks throughout the Spring 2011 term. Although all peer leaders present during the Biology 200 class each week received the same training for the PLTL workshops, the experience of each peer leader with the students in the workshops may have been very different. While some peer leaders may have focused on the problem sets with their group of students, other peer leaders may have focused on study tips or review of material for Biology 123 course exams. Even if the peer leaders focused on the problem sets, the implementation of the tasks could have varied substantially. Although the problems in the problem sets were typical of introductory level biology, the problems themselves were not explicitly designed to improve critical thinking skills; rather the implementation of those problems was designed to improve critical thinking skills. Simply answering the questions in the problem sets, without integrating factors that could potentially influence their critical thinking skills (interacting with peers and faculty, class discussion, and writing), was not likely to improve critical thinking skills. The efficacy of the PLTL tasks on increasing peer leaders' critical thinking skills depended on the peer leader commitment to implementing the tasks the way in which they were trained. These differences in the PLTL workshop experiences could have resulted in varying levels of critical thinking gains.

The treatment for this study was provided during the Biology 200 class time. Biology 200 was only a two-credit course, so students in the course were only required to be in class for a limited number of hours each week. Because the peer leaders in the course had to facilitate a 1-hr workshop each week, they had only one 55-minute class with the learning specialist each week. With limited class time, the learning specialist was not able to cover a lot of teaching and learning theory. Following debriefing of the previous week's workshop, peer leaders would have only enough time to focus on the problem sets for the upcoming week. Readings related to teaching and learning theory were assigned as homework, so the study was limited by the willingness of the peer leaders to complete the assignments.

Conceptual Assumptions

To determine the effects of the treatment, this study assumed that the instrument utilized could be reliably used to measure undergraduate students' critical thinking skills and that critical thinking skills could be affected by the PLTL training and leadership experience. An additional assumption of the study was that participants who took the critical thinking questionnaire were able to accurately perceive their level of critical thinking skills and how those skills changed over the duration of the study.

Outline of the Remainder of the Dissertation

The remainder of this dissertation is divided into four chapters. Chapter 2 presents a review of relevant literature specifically related to both the PLTL instructional model and critical thinking. Chapter 3 describes the methods and procedures used throughout the duration of the study, while Chapter 4 presents the findings of the data analyses, as well as a discussion of those findings. The final chapter provides a summary of the dissertation and recommendations for practice and further research.

CHAPTER 2: LITERATURE REVIEW

Overview

This chapter consists of a review of the literature relevant to the study of peer-led team learning (PLTL) and critical thinking gains. The review will begin with an in-depth look at the research that has been done with respect to PLTL, focusing on the effectiveness of this pedagogical approach on both students and peer leaders. A discussion of prior research on critical thinking will follow, with particular attention paid to factors that have been found to influence critical thinking skills. The peer leader role of the PLTL approach incorporates many of the factors known to enhance critical thinking skills of students, yet there is a lack of research on the relationship between PLTL and critical thinking gains.

Peer-Led Team Learning

Peer-led team learning (PLTL) is an instructional approach that provides an environment for students to engage in intellectual discussions and work in problem-solving teams under the guidance of a peer leader (Woodward, Gosser, and Weiner, 1993). Like many cooperative learning strategies, the PLTL model encourages students to actively engage in their own learning. Differing from traditional cooperative learning strategies, however, this model provides some guidance to the students in a setting outside of lecture and without teacher intervention (Cracolice and Deming, 2001).

The PLTL model involves teams of six to eight students, often referred to as the workshop, each with a peer leader who has recently and successfully completed the same course in which the students are enrolled. Prior success in the course, as a qualification for peer leaders, is generally defined as having earned a grade of A or B in the course. In addition, peer leaders should demonstrate good communication skills and leadership potential. The peer leaders facilitate group work amongst the team of students and are not responsible for providing answers to any of the problems. Because they are usually neither content experts nor experienced facilitators, peer leaders take part in a leader training program in which the course instructor and an education specialist prepare the leaders to guide student-student interactions (Tien, Roth and Kampmeier, 2004).

The PLTL model includes six critical components for its implementation (Gafney, 2001b):

1. The organization promotes learning, taking into consideration the limits on group size, space, time, noise level, and teaching resources.
2. The materials encourage active learning, work well in groups, and are appropriately challenging and integrated with the course.
3. The peer leaders are well trained and closely supervised.
4. The instructor is involved with the workshops and peer leaders.
5. The workshops are an integral part of the course, coordinated with the lecture, laboratory, and exams.
6. The school supports the program.

Since the introduction of the model into introductory chemistry courses, the PLTL approach has been implemented into many undergraduate science courses, and its effectiveness has been documented in regards to both students participating in the workshops and peer leaders facilitating the workshops.

Effects of PLTL on Students

Gafney (2001a) reported on a number of comparison studies that were done to determine the effect of the PLTL workshops on the grade performance of students in general chemistry, organic chemistry, and human anatomy and physiology. While some compared treatment groups and control groups within the same course, others compared current students to students of prior years in the course. Five universities and one community college were included in the report. Results showed that each study produced data illustrating a positive effect on grade performance for PLTL students when compared to non-PLTL students, with increases in the percentage of students receiving A, B, or C grades. These findings appear to indicate that the PLTL model can increase student achievement in university science courses. These studies did not, however, have all the appropriate controls of randomization nor comparable experiences for students outside of the PLTL workshops.

Determination of student grades is very subjective in nature. Because of this, skeptics of the PLTL model can claim that increases in students' grade performance alone do not provide sufficient evidence for implementation of the model. In an effort to minimize subjectivity on grade performance, Alger and Bahi (2004) tested to see the effects of PLTL on grade performance of faculty-generated exams, as well as on a more concept-oriented American Chemical Society (ACS) final exam in a general chemistry course. In this study, a single section of general chemistry PLTL students (less than 50) was compared to non-PLTL students from the previous academic year at a university in the Northwestern United States. Results showed that while faculty-generated exam scores increased, no significant difference in ACS exam scores was found between PLTL and non-PLTL groups for the first semester. Improvements were seen, however, in the second semester comparison of ACS exam scores. Wamser (2006) also found that self-selected PLTL students in an organic chemistry course at a university in the Northwestern United States increased their national percentile standings on the standardized ACS Organic Chemistry exam, with average percentile scores for PLTL students at the 77th percentile versus the 69th percentile for non-PLTL students.

Peteroy-Kelly (2007) assessed the impact of the PLTL model on the conceptual reasoning skills of students enrolled in a large introductory biology course at a university in the Northeastern United States. Participants were evaluated both before and after the course via three assessment tools: pre- and post-tests (n=115 and 85 respectively), a survey, and final grades. The results of this study indicated that the PLTL model improved both the conceptual reasoning skills and overall performance of students in the course.

In addition to improved grade performance, many studies indicate positive effects on student retention, with a decreased percentage of PLTL students that fail or withdraw from a course relative to non-PLTL students. Tien, Roth and Kampmeier (2002) quantitatively and qualitatively evaluated the impact of PLTL on student performance, retention, and attitudes about a first semester organic chemistry course. Over eight years, more than 2000 students located in a small research university in Eastern United States participated in the study. PLTL students were compared to traditional recitation students from previous years. In the traditional recitations, a chemistry graduate teaching assistant spent 1.25 hours a week answering student questions and explaining how to solve assigned problems. Results of the comparison showed statistically significant improvements in PLTL student performance, retention and attitudes about the course, regardless of demographic factors such as gender and ethnicity. Based on these findings, the authors suggest the use of peer leaders and the PLTL instructional model as a means of bringing about change in undergraduate science courses and possibly retaining students in the sciences. Wamser (2006) found similar data with respect to retention in the course. PLTL students had a substantially higher retention rate (57%) when compared to non-PLTL students (28%), indicating that PLTL students were about twice as likely to complete all three terms of organic chemistry in the same academic year.

Stewart, Amar, and Bruce (2007) also introduced PLTL into a large general chemistry course to determine whether benefits of a small group learning environment could be extended to students without imposing a radical change in format to their primarily "lecture" course of greater than 500 students. Longitudinal comparisons of success rates were made over a six year time period. Success rates prior to the introduction of PLTL averaged around 60%, while success rates for the years following the introduction of PLTL averaged around 75%. Based on the findings of increased student grades and improved retention rates in what is considered to be a "gatekeeper" course, the authors suggest that implementation of PLTL can create an active learning environment in a large, introductory course and help to catalyze a shift towards student-centered teaching/learning.

Hockings, DeAngelis and Frey (2008) demonstrated similar results in a general chemistry course. Because students self-selected into the PLTL program, efforts were made by the researchers to control for measurable differences between PLTL participants and non-PLTL participants. Regardless of characteristic differences, PLTL students statistically outperformed non-PLTL students in terms of final grade, averaging about one-third of a letter grade higher in the course (an average of B versus B-), and PLTL students were less likely to withdraw from the course after the first two weeks of the semester statistically illustrating a slightly higher retention rate. Positive attitudes toward PLTL as a learning model and toward the study of chemistry in general were revealed by a survey of the students, consistent with the findings of Tien, Roth, and Kampmeier (2002).

The previous discussion demonstrates that positive effects of PLTL on grade performance and student retention have been well established in introductory science lecture courses. McCreary, Golde, and Koeske (2006) demonstrated the positive effect of PLTL on student performance in a general chemistry lab at a university located in the Northeastern United States. In two phases, around 275 students participated in a comparative study of PLTL lab sections to conventional lab sections. While the PLTL lab sections involved a more inquiry-based format, the conventional lab sections involved more of an "expository (cookbook) approach". Results showed that PLTL students performed better than conventionally taught students on a written exam at the end of the term. PLTL students achieved a higher percentage of good responses, lower percentage of poor responses, and wrote longer answers. While these findings from a laboratory course mimic those from lecture settings, it is difficult to determine which aspects of the PLTL model are responsible for improvements in student performance simply because the labs were carried out with an inquiry-based approach. Although an active approach to learning is consistent with the inquiry model, PLTL students in these lab sections were not trying to discover a law of chemistry; rather they were attempting to construct their own approach to successfully complete the lab activities.

Two additional studies of the effectiveness of the PLTL model focused on the integration of the PLTL model with another instructional approach. Hewlett (2004) tested the efficacy of an integrated one-hour instructional session including both PLTL and the Case Study Method (CSM). CSM is an instructional model that fosters critical thinking, and PLTL provides the social context that allows students to develop their thinking as they would need to do in a real world setting. 173 students in General Chemistry, Human Anatomy and Physiology, and Abnormal Psychology at a community college in the Northeastern United States participated in the study. Results showed that students in the CSM/PLTL session were more likely to obtain final grades of A, B, or C than students in the non-CSM/PLTL session. Based on these findings, there is support for the integration of the two instructional models.

Lewis and Lewis (2005) evaluated the effectiveness of guided inquiry methods within a typical PLTL workshop, an integration known as peer-led guided inquiry (PLGI). 264 students in a general chemistry course at a university in the Southeastern United States participated in a comparative study. Results showed that students in the PLGI section outperformed the non-PLGI section on both instructor-constructed exams and an ACS exam. This integration is also supported, but in an integrated instructional approach such as the two discussed above, it is difficult to determine the contributions of each instructional model to the improved grade performance.

While the PLTL instructional model places students who have previously taken and done well in a course to be peer leaders of small groups of students, two studies examined the effectiveness of in-class peer leaders in the PLTL model. Lord, Shelly, and Zimmerman (2007) utilized in-class members to lead peer groups enrolled in a botany course at a midsized Eastern University. Results showed that when compared to students from previous years, the peer-led students performed as well or better. Survey results also revealed that students preferred to work in teams and felt they learned more that way.

Schray, Russo, Egolf, Lademan, and Gelormo (2009) performed a comparative study of in-class peer leaders to standard peer leaders. Over a four-year span, 120 groups of no more than 8 students in an organic chemistry course at a four-year college in the Northeastern United States participated in the study. Results showed that academic performance of students within each of the groups were equivalent, with only 3 of 29 grading exercises showing a significant difference. In addition, student attitudes towards the two types of leaders were also virtually identical. Based on these findings, that in-class peer leaders can perform group leadership as effectively as standard peer leaders, the authors suggest that implementation of this pedagogical model is easier due to cost and availability of leaders; making this model feasible even for a 2-year college.

Effects of PLTL on Peer Leaders

As evident by the previous section, there has been a great deal of research on effectiveness of the PLTL model for students taking the workshops. Much less research has focused on the effects of the PLTL model on peer leaders. Of such research that has been done, most studies focus on self-report or anecdotal evidence of leader benefits with little information on grade performance or other important collegiate skills, such as improved conceptual reasoning, content knowledge, or critical thinking.

Several studies have focused on the benefits reported by leaders during the leadership experience. Tenney and Houck (2004) assessed the effect of peer leadership of the PLTL model. More than 60 peer leaders from a university in the Northwestern United States participated in the study. Results of formative assessment tools, journal writing, reflection essays and anonymous surveys, revealed five major benefits as reported by the peer leaders: increased content knowledge, improved relationship with course instructor, enhanced teaching skills, improved people skills, and financial compensation.

Micari, Streitwieser, and Light (2006) also investigated peer leaders at a Northwestern University during the leadership experience. Qualitative data was collected from 168 survey participants, 13 focus groups, and 8 individual in-depth interviews on the leadership role and its effect on the leaders. Results indicated that peer leaders thought their cognitive skills improved, as well as their communication and pedagogical skills. Leaders reported additional benefits to their professional growth. Based on these findings, the authors suggest the PLTL training and leadership experience provides benefits that may not be available in a traditional undergraduate curriculum.

Johnson and Loui (2009) collected only journal entries written by PLTL leaders during their leadership experience to determine peer leader benefits. Fourteen peer leaders from a Midwestern university participated in the study. Results showed that leader benefits included increased self-confidence, increased awareness of intellectual diversity, and increased interest in teaching. While these studies demonstrate clear benefits to the student leaders, long-term benefits such as continued interest in teaching, improved cognitive skills, and continued confidence cannot be claimed.

In contrast to the studies previously discussed, Gafney and Varma-Nelson (2002) investigated how graduates who were once peer leaders in the PLTL program viewed their leadership experience several years after college. Twenty-six former peer leaders from a Midwestern university participated in the study. Results of a Likert-type survey showed that respondents unanimously agreed that their leadership experience was among their most productive learning experiences. Peer leaders felt that not only was their content reinforced but that they had gained confidence in interacting with other people.

Following their pilot survey in 2002, Gafney and Varma-Nelson (2007) studied the long-term effects of the PLTL experience on peer leaders. More than 570 former peer leaders from eleven institutions were sent surveys and 119 respondents completed the survey. Results confirmed previous evidence that leaders reap benefits such as improving their own learning, developing confidence and perseverance, and improving team-related skills. The findings suggest that leadership experiences, such as the PLTL experience, lead to personal and professional benefits even after college is complete.

Unlike the other studies on peer leadership that simply reported student benefits of the PLTL training and leadership experience, Blake (2001) tried to quantify some of the leader-reported content knowledge gains. Student leaders from the general chemistry course at a Midwestern university participated in the study. Results of a pre- and post-test indicated that student leaders did increase their knowledge of chemistry content. Based on these findings, the author suggests that being a workshop leader provides critical reinforcement of key concepts that prevents the typical deterioration of knowledge over time. Because this was a very superficial analysis of leader content gains, more research is needed to quantify peer leaders gains.

Role of the Peer Leader

To understand how participating in PLTL might be beneficial to peer leaders, it is important to understand more fully the role of the peer leader in the PLTL process. Prior to leading a weekly workshop, the peer leader is involved in a training program that focuses on both classroom knowledge and pedagogical content knowledge (Tien, Roth, and Kampmeier, 2004). Classroom knowledge refers to specific knowledge of the students and the classroom environment, including awareness or motivation and interpersonal dynamics, while pedagogical content knowledge refers to knowing the content, as well as how to teach it. Although the leaders' training begins with an initial session to introduce the ideas and goals of peer-led team learning, the training sessions continue through weekly discussions with the instructor and learning specialist who model a collaborative instructional model. While the instructor focuses on the content aspect of the sessions, the learning specialist focuses on applying learning theory to teaching the specific content (Gosser, Cracolice, Kampmeier, Roth, Strozak, and Varma-Nelson, 2001).

Prior to each weekly meeting, peer leaders are assigned course readings from the Handbook for Team Leaders (Roth, Goldstein, and Marcus, 2001). Readings focus on particular issues that may come up in the student workshops. Peer leaders then discuss these readings with the class and determine how to apply ideas into their individual workshops. In addition to discussions on pedagogy that take place weekly, peer leaders are asked to keep a weekly journal to reflect on how they applied various pedagogical techniques in their workshop groups.

A portion of each weekly class is devoted to peer leaders rehearsing the workshop problems. Much like their students will do during the workshops, leaders work in teams to brainstorm ways to solve the problems (Tien, Roth, and Kampmeier, 2004). The instructor will guide the leaders by answering questions, making connections to previous material, identifying misconceptions, and offering insight into his/her own thought process. He/she will not, however, provide the answers to the problems. The leaders are responsible for constructing their own answers to the problems by coming up with approaches to work on them. In this way, the leader training sessions model the same facilitative role that the leaders should utilize in their own workshops to scaffold their students' learning.

The peer leader begins a typical session by breaking their group of students into smaller groups and assigning problems. While the students in the workshop work toward solving the problems, the leader will facilitate by summarizing various student ideas, constructing diagrams suggested by students, or recording steps in student solutions (Cracolice and Deming, 2001). Leaders may prompt students toward problem solutions by offering advice about resources to use, suggesting applications used in previous problems, or helping them through their thought processes.

Throughout the leadership experience, peer leaders are engaged in many active learning strategies that they utilize to construct their own understanding of various concepts. Leaders are involved in weekly discussions with both their peers and instructors. In these discussions, leaders are provided with feedback on their own thought processes and are able to provide feedback on the thoughts of others. Reflection on the leaders' thought processes also occurs through the weekly writing task about their leadership experience. These aspects of the leadership experience may be of importance to the development of critical thinking skills; skills that are necessary for students to adapt to a changing world that presents many challenges in both personal and professional lives.

Critical Thinking

Within the literature on critical thinking, there is not one definition of the construct. Critical thinking overlaps with many constructs including reflective thinking, creative thinking, problem-solving, higher-order thinking, and metacognition. The lack of consensus on a collective definition of critical thinking comes from the combination of philosophical and psychological theories underlying the construct, yet various definitions share common aspects.

To illustrate this complexity within critical thinking theory, several definitions will be discussed. The overlap of critical thinking and higher-order thinking is made clear through Bloom's Taxonomy of educational objectives that suggest a hierarchy of cognitive skills (Ennis, 1993). Scientific methodologies can be used as an example of the use of higher-order thinking skills because they require analysis, synthesis, and evaluation of information. Kurfiss' (1988) definition of critical thinking seems to align with scientific methodologies as it suggests that critical thinking is "an investigation whose purpose it is to explore a situation, phenomenon, question, or problem to arrive at a hypothesis or conclusion about it that integrates all available information and that can therefore be convincingly justified" (as cited by Walther, 2009).

Ennis (1993) discusses how the upper levels of Bloom's taxonomy, which are often used synonymously with critical thinking, are too vague and not really hierarchical. He does, however, agree that it is a good beginning. Ennis (1985; 1993) elaborated on his definition by including the reflective nature of critical thinking: "reasonable, reflective thinking that is focused on deciding what to believe or do". He explains that reflectively going about what to believe or do requires both abilities and dispositions. In a similar definition, Paul (1990) added the dimension of metacognition to his definition by suggesting that there must be "thinking about one's thinking" which requires the ability and disposition to evaluate beliefs.

By combining many philosophical and psychological theorists' definitions such as above, the American Philosophical Association (APA) Delphi Panel yielded the following conceptualization of critical thinking that characterizes a set of cognitive skills and the disposition toward using them:

> We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based…The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to

reconsider…and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit…(Facione, 1990a).

This conceptualization of critical thinking made it possible to focus on appropriate assessments of critical thinking skills which could inform teachers about their success in teaching students to think critically (Ennis, 1993) and led to the development of the standardized California Critical Thinking Skills Test (CCTST) to measure six cognitive skills identified by the Delphi panel as essential (Facione, 1990b).

Because the APA definition of critical thinking is based on the most current consensus definition of critical thinking that includes cognitive skills and dispositions and was used as the theoretical basis for designing the CCTST, this will be the definition adopted for this study; to determine if the PLTL model can enhance critical thinking skills of undergraduate peer leaders.

While there is a vast amount of research on critical thinking, this section will review only the literature related to factors or influences that affect students' critical thinking skills; those that are linked to the PLTL training and leadership experience in particular. Although there are many definitions and assessments of critical thinking used in the literature, instructional interventions that can enhance critical thinking are generally consistent.

Since the 1980's, a primary goal of colleges and universities has been to help students develop the ability to think critically (Commission on the Humanities, 1980; McMillan, 1987). Critical thinking is a skill that will last throughout a lifetime, regardless of what content may or may not be forgotten. Being an independent, critical thinker will allow individuals to be contributing citizens to their profession and society, long after their academic career is over. Fostering critical thinking skills requires colleges and universities to adopt effective instructional strategies that will enhance such skills. For this reason, much research has been devoted to determining what teaching approaches inhibit or enhance students' ability to think well.

Smith (1977, 1981) found that three instruction-related factors across both individuals and classes make a difference in gains in critical thinking: the extent to which faculty members encouraged, praised or used student ideas; the amount and cognitive level of student participation in class; and the amount of interaction among the students in the course (as cited by Terenzini, Springer, Pascarella, and Nora, 1995; Tsui, 2002). Terenzini, Theophilides, and Lorang (1984) also found that students' level of classroom involvement, including contact with faculty members inside or outside the classroom, had a significantly positive effect on an academic skills measure that included aspects of critical thinking. Similarly, Ory and Braskamp (1988) provided further evidence that students' quality of involvement in curricular activities, including interactions with their peers and with faculty members, positively relates to gains in critical thinking.

In a review of studies on undergraduate involvement on critical thinking such as these, consistent findings were presented as Pascarella and Terenzini (1991) concluded that there was strong evidence that student interaction with faculty and peers had a positive impact on critical thinking. Following their synthesis, the literature on student involvement and critical thinking began to report contradictory findings. Based on the research discrepancies, Gellin (2003) conducted a meta-analysis of eight studies to determine the effect of Greek life, clubs and organizations, faculty interaction, peer interaction, living on campus, and employment on critical thinking. Findings suggested that students who were involved in clubs and organizations, living on campus, and interacting with peers experienced effect gains, as measured by the Pearson product-moment correlation coefficient r; specifically noted is the .14 effect gain for peer interaction. Pearson *r* effect sizes were interpreted by the following guidelines: *r*=.10 is a small effect; *r*=.30 is a medium effect; and *r*=.50 is a large effect (Rosenthal, 1991; as cited by Gellin, 2003). While this analysis had varying effect sizes for faculty interaction and was not consistent with the findings of Pascarella and Terenzini (1991), differences among faculty and their interactions with students may account for the variance observed.

These studies are important to consider with regard to the PLTL model as they indicate that students' participation and interaction with peers can positively influence critical thinking skills. Peer leaders are involved not only in participation of the class they are facilitating, but they are also involved in direct participation with their peers and instructor in the weekly meetings in which they themselves have to work through various problems they will assign their own group of students.

Through a review of twenty-seven studies, McMillan (1987) considered the effects of instructional methods, courses, programs, and general college experiences on changes in college students' critical thinking. Results of the review failed to support the use of any specific instructional interventions to enhance critical thinking. However, several factors were discussed to account for this overall finding. The short length of time in one semester, the lack of curriculum specific measurement instruments, and the design of many studies made it difficult to interpret results. This finding implied that research should continue in the area of enhancing college students' critical thinking so that a better foundation may be provided for the implementation of various instructional programs that universities have been called upon to implement.

As research in the area continued, Terenzini, Springer, Pascarella, and Nora (1995) conducted one of a few studies on critical thinking gains in which formal academic activities and out-of-class experiences were examined simultaneously in first year college students at a large research university in the Midwest. Critical thinking was found to be positively and significantly related to only a few classroom and out-of-class experiences. However, after controlling for pre-college level of critical thinking, only hours per week spent studying remained significant. It is important to note that without controlling for pre-college critical thinking ability, the number of courses taken in science showed a positive effect on critical thinking. Both of these findings have important implications for peer leaders of an introductory biology workshop. In addition to adding a science course to their program of studies, leaders would be required to spend more hours studying the material by not only spending extra hours in the workshop training but also in preparation for the workshop itself.

With such discouraging findings from some of the previously discussed studies, some have concluded that teaching methods are irrelevant to the development of critical thinking. Still, other researchers have continued to investigate how courses and instruction affect critical thinking. Tsui (1999) explored how ordinary class experiences and instructional techniques impact students' critical thinking. By utilizing a national sample of students from 392 colleges and universities across the country, eleven categories of courses and six categories of teaching methods were investigated to identify which categories were associated with self-reported increases in critical thinking ability. Results of the study revealed that both the type of course and the type of instruction could have a positive impact on improvement of critical thinking. Science courses were among the courses found to be positively related to students' critical thinking gains. Types of effective instruction included working on an independent research project, working on a group project, giving a class presentation, and taking essay exams. All of these instructional techniques ask students to construct responses or answers to a problem, rather than merely memorizing, recognizing, or selecting correct answers from provided responses. Findings, therefore, suggest that active learning techniques can be effective at improving critical thinking. This study is limited, however, due to the lack of objectivity in the self-reported instrument used to measure critical thinking.

Although studies such as this show a positive relationship between critical thinking and instructional factors, many are criticized for their reliance on standardized tests and students' responses that limit the findings. For this reason, Tsui (2002) employed a qualitative case studies approach to four institutions to provide contextual evidence for the types of pedagogy that are associated with reported enhancement of critical thinking abilities. Results suggested writing and class discussions were linked to the development of critical thinking. Writing often entails reviewing and providing feedback on other students' work. This assessment of others' work likely allows students to use their critical thinking skills as they attempt to comprehend, as well as improve their own writing. Class discussions provide an active learning environment that allows students to verbalize their thoughts, which may also facilitate critical thinking by reflecting on their peers' views while being provided feedback on their own views. Due to the self-assessment of critical thinking growth, causal relationships cannot be made between writing and class discussions with critical thinking, but the research did show that institutions where these two pedagogies took place had a higher number of students reporting greater critical thinking. These results were consistent with previous results by Pascarella and Terenzini (1991) who found class discussion to be more effective than lecturing when the goal is to improve higher-order cognitive skills like critical thinking. Within the PLTL leadership training meetings and the workshops themselves, peer leaders are actively involved in discussion with other students. They have the opportunity to receive feedback from peers providing them an environment to foster critical thinking. In addition, leaders may improve critical thinking skills through the writing process of keeping their weekly journals.

Abrami et al. (2008) performed a recent meta-analysis of the empirical evidence on the impact of instruction on students' critical thinking skills. Over 3700 studies from the 1960's through 2005 were included in the analysis. Unlike some previous results of reviews that found that instructional interventions had little effect on the development of critical thinking skills (McMillan, 1987), the results of this meta-analysis show that instructional interventions can be effective in enhancing students' critical thinking. The mixed method, in which critical thinking is taught independently within a specific content course, instructor training, and collaborative learning conditions were among specific interventions found to have a positive effect on development of students' critical thinking skills. Based on these findings, the authors suggest that educators take steps to make critical thinking objectives explicit in courses and include them in training programs for faculty.

Pithers and Soden (2000) reviewed methods and conceptions of teaching that are likely to inhibit or enhance critical thinking. Inhibitory teaching approaches included simply agreeing or disagreeing, just demonstrating and explaining, cutting off student responses, using reproof rather than praise, shaking the learner's confidence in new ideas, or using basic retrieval or recall types of questions. Teacher beliefs that the lecturer can learn nothing from students, that critical thinking is the job of the lecturer, and that the "right" answer is important (rather than the thinking behind attaining the answer) were among other ways discussed to inhibit critical thinking. In contrast, methods thought to enhance critical thinking included teaching from multiple perspectives and focusing on linkages in content to explore various themes. Allowing for this awareness of different thoughts depending on the content provides students the chance to be active, ask questions, seek new information and link it to other questions they may have. Rejection of these critical thinking inhibitors was proposed as a way to look for novel teaching approaches that allow the student to develop more control and independence over their learning. Finally, having students consciously reflect on their core ideas and assisting them in analyzing these core ideas can bring about changes in critical thinking. Challenging students' current ideas facilitates the formation of new hypotheses and interpretation of information.

Pithers and Soden (2000) continued their review by discussing metacognitive approaches to help students to think well. Modeling ways of thinking and scaffolding were among the approaches to help students to learn to think as they learned their discipline. Scaffolding is a process in which the teacher moves the student's thinking forward through a series of systematic questions that lead the student to understanding. Derived from the work of Vygotsky (1978), scaffolding can enhance the learner's zone of proximal development which involves more critical thought. Developing critical thinking can be accomplished more successfully with a student-centered approach to teaching and learning. The authors specifically mention small-group tutorials and well-designed problem based courses as likely avenues for encouraging critical thinking. Based on their review of the literature, there are implications for the leaders in the PLTL instructional model. Peer leaders are involved in a small-group, student-centered instructional model in which they are active participants in a weekly meeting where a scaffolding process helps them in the process of solving content-related problems. Not only can this enhance their own zone of proximal development, but they will also be working with their peers who are closer to their zone of proximal development than the instructor.

While Pithers and Soden outlined problem-based courses as a way forward to enhance critical thinking, research on problem-based learning (PBL) and critical thinking has been conducted and found to be an educational strategy that promotes critical thinking. In one such study, Tiwari, Lai, So, and Yuen (2006) compared the effects of PBL and lecturing approaches on the development of students' critical thinking. 79 nursing students at a university in Hong Kong participated in the study. Based on the California Critical Thinking Disposition Inventory results, PBL students had significantly higher overall critical thinking disposition (motivation to value and utilize critical thinking) scores than the lecture students on completion of the course. Higher scores continued for two years afterward. While self-report by students and limiting the study to nursing students makes it impossible to generalize, the findings are consistent in suggesting that PBL can improve critical thinking.

Studies of the effectiveness of PBL are of particular importance to PLTL because they are similar pedagogies. Although PBL was developed and utilized primarily in medical education within the construct of the lecture, adaptations were made to implement the instructional model into the college and university setting. PLTL, just as PBL, situates students in their zone of proximal development by presenting challenging problems that they can't solve easily on their own but can by interacting with peer members of the team (Eberlein et al, 2008). If the student-centered pedagogical approach of PBL can be effective at improving critical thinking skills, placing students in a PLTL setting may also improve critical thinking.

PLTL and Critical Thinking

Of the many studies that have examined the effectiveness of the PLTL model, only one tested the model as a predictor of critical thinking gains. Quitadamo, Brahler, and Crouch (2009) examined the impact of PLTL on critical thinking gains in six undergraduate science and math courses at a research university in the Pacific Northwest. Results showed that the PLTL model had a positive impact on critical thinking gains in science but not in math courses, regardless of gender, ethnicity, or other variables. In addition, grade performance and retention improved, particularly for females. Based on these findings, the authors suggest that continued development of the PLTL model may serve to increase critical thinking gains in undergraduate students. Research on the leadership experience of PLTL on critical thinking gains has yet to be explored.

As evident from the previous literature discussion on PLTL and critical thinking, peer leaders are engaged in many activities that have been shown to improve critical thinking skills. Peer and faculty interaction, class discussion, and writing tasks are involved in their collaborative leadership experience. Instructors utilize a scaffolding approach to model how leaders should help their own students with their thought processes, and leaders are engaged in weekly problem solving sessions in which they construct their own understanding. Therefore, the PLTL training and leadership experience should lead to better critical thinking skills.

CHAPTER 3: METHODS AND PROCEDURES

Overview

This chapter begins with a detailed description of the participants in this study, including procedures for recruiting participants and participant demographics for both the treatment and control groups. The treatment in this study, as well as the treatment procedures are then presented for the participants in the PLTL training and leadership experience. The instrument used in this study, the California Critical Thinking Skills Test (CCTST), is described, and its reliability is discussed prior to a detailed description of procedures in administration of the instrument. Finally, procedures in data analyses are discussed, along with any methodological assumptions of the study.

Sample

Participants and Location of Research

Undergraduate students who were enrolled in an introductory biology course during the Spring 2009 or 2010 academic terms at a large, research university in the Northeastern United States were included in the study. In keeping with the conventional PLTL model, only those students who had obtained a final course grade of an A or B were asked to participate. Because the second term of the biology course was the course in which the PLTL model was implemented, a sample of students from this natural group was appropriate. The number of participants depended on how many students both received an A or B and were interested in participating as a PLTL leader. Of the students who were interested, two groups were established: one group of students who were interested and able to complete the requirements of being a PLTL leader (treatment group) and one group of students who were interested but not able to be a leader due to various time/schedule constraints (control group). The students who were able to complete the requirements of being a PLTL leader were enrolled in a Biology 200 course on PLTL leadership.

The Biology 200: Selected Topics course has been offered to undergraduates who have completed the first semester of introductory biology and are interested in science careers. As a way of introducing students to various areas of research in the life sciences, this special topics course is taught by teaching assistants in the biology department, and the topic of the course is of particular interest to the teaching assistant. In the past, topics have included pathophysiology, medical ecology, and biotechnology and bioethics (Wiles, 2011b).

Recruitment of Participants

Participants in both the treatment group and control group were asked to participate in this research study. An invitation to participate was sent to over 600 students through email solicitation prior to the start of the Spring 2011 semester (Appendix A). Within the email, it was explained that prior performance in Biology 123 afforded students an opportunity for participating in an experience that could be of benefit to both themselves and their peers. A meeting time and location was provided for an organizational meeting that would provide information about the research study.

An organizational meeting was held during the first week of classes of the Spring 2011 semester, and over 100 students attended the meeting. During the meeting, the research study was explained, student questions were addressed, and students were invited to participate in the research. If students were interested in participating, they were asked to stay and complete a consent form (Appendix B) and a short, demographic survey (Appendix C) to determine information regarding control variables for the data analyses of the study. They were also asked to turn in a schedule of their available times each day for purposes of determining the meeting time for Biology 200. Following completion of the consent form and demographic survey, participants were given an objective pre-test measure of critical thinking; prior to any participation by the treatment group in the PLTL instructional model.

The consent form, demographic questionnaire, and the pre-test were administered to the interested participants by a third party. The researcher left the organizational meeting after inviting students to participate, at which time the third party administrator took over the data collection procedures. The third party administrator collected all documents from the students at the organizational meeting and kept them in a secure location. Only availability times were provided to the researcher to determine the best time to offer Biology 200: Peer-Led Team Learning-A Leadership Experience.

Participant Demographics

A distribution of class standing, gender, ethnicity, major, and number of science courses during and prior to the Spring 2011 semester (Tables 1, 2, 3, and 4) indicated that the majority of the students were sophomores and juniors. The PLTL group of students was comprised primarily of juniors, while the non-PLTL group was comprised primarily of sophomores. Gender distribution of the PLTL group was evenly matched to the non-PLTL group. Over 60% of the participants were White, with Hispanic/Latino, African American, Asian, and Other students comprising the remainder in decreasing frequency. Eighty percent of the participants were science majors, and over 60% of them had taken more than 6 science courses prior to the start of the Spring 2011 term. The PLTL group, however, had taken a much higher percentage of science courses than the non-PLTL group prior to the start of the semester. The number of science courses taken during the Spring 2011 semester was more evenly matched between the PLTL group and the non-PLTL group, with almost 75% of the participants taking 2, 3, or 4 science courses.

Treatment

Each year, there is a significant population of students interested in attaining leadership experience through the introductory biology course. For this reason, Biology 200: Peer-Led Team Learning-A Leadership Experience was offered (Appendix D). The course was a 2-credit course that related educational research literature on students and learning to classroom applications in problem-solving activities. Students who took the Biology 200 PLTL leadership course were trained to be leaders of a small, problem-solving group of students. Course requirements included running a 1-hour problem-solving workshop each week and keeping attendance records throughout the Spring 2011 semester.

Within the constructs of Biology 200: Peer-Led Team Learning-A Leadership Experience, it was possible to establish the treatment group for this study. Although the course itself was the treatment provided during the normal class time to those who wished to participate, students in the Biology 200 course were not required to participate in any data collection activities. Whether participants were in the treatment group or control group for this study, participation in data collection required an equal and minimal amount of time. Students enrolled in the Biology 200 course were engaged in the same instructional activities regardless of whether or not they chose to participate in the research.

The PLTL training and leadership experience was the independent variable provided to the treatment group to determine if the dependent variable, critical thinking, improved as a result.

Other controlling variables such as gender, ethnicity, class standing (Fr, So, Jr, or Sr), major, and the number of science courses taken prior to and during the semester were used as co-variables in the data analyses to determine their effect, if any, on critical thinking.

Procedures and Treatment Administration

During the informational meeting regarding this research study, interested participants were asked to provide their availability of times each day during the week. Following collection of the student availabilities, the third party administrator provided the researcher with 75 students' availability schedules. The researcher reviewed the 75 schedules and determined that the greatest number of students could attend the Biology 200 course Tuesday at 2pm. For this reason, the Biology 200: Peer-Led Team Learning-A Leadership Experience course was offered at that time. All 75 participants were notified by the third party administrator about the time the course would be offered and were told to contact her for permission to enter the course. The first 37 students to contact the administrator were provided permission numbers to enroll in the Biology 200 course. All other participants were notified by the third party administrator that the course was full but that their participation in the critical thinking post-test would be necessary at the end of the semester. Participants enrolled in Biology 200: Peer-Led Team Learning-A Leadership Experience became the treatment group, while participants not enrolled in the course became the control group for the study.

Students in the Biology 200 PLTL course were asked to provide three 1-hour time blocks for which they were available to run a workshop session during the week. After receiving all 37 students' availabilities, each student enrolled in the Biology 200 course was assigned one 1-hour time during the week to run a PLTL workshop. There were between 6 and 10 PLTL workshops scheduled each day, Monday through Friday, during the week. The schedule of PLTL workshop times was then posted on the Biology 123 Blackboard site, so students currently enrolled in Biology 123 could sign up to participate in the PLTL workshops. To minimize enrollment in each workshop due to friendship or discrimination, peer leaders' names were not provided with the available workshop times, nor were the students enrolling able to see the names of the other students who had already enrolled in each workshop. Each workshop was capped at 8 students. Once the session was full, the session time would no longer appear available through Blackboard. Students in the Biology 123 course who could not enroll in any of the remaining available times contacted the BIO 200 instructor. The instructor added them into a section that fit their schedule, and some PLTL workshops had 10 students enrolled.

Participants in the treatment group engaged in a weekly PLTL instructional model. The peer leaders met with a learning specialist for one 55-minute class each week for 13 weeks to discuss teaching and learning theory and how to apply it conceptually, debrief on previous weeks' sessions, and practice problem-solving strategies by collaboratively working on instructor-generated content problems.

During the first Biology 200 PLTL class, the learning specialist discussed the PLTL instructional model. Students were then asked to discuss what they believed the role of the peer leader was in the PLTL workshops. Following the group discussion, the first day workshop agenda was given to the peer leaders (Appendix E). Peer leaders were also provided with a PLTL leader handbook that included many assigned readings on learning theory and group dynamics.

At the start of each class succeeding the first, the learning specialist would either do a short activity related to the weekly reading assignment or ask if there were any questions about the assigned readings.   Peer leaders were then able to debrief on the previous weeks' sessions. During the debriefing time, peer leaders would share personal experiences with the other leaders, as well as the learning specialist. They would both offer and receive suggestions on how to handle various issues that arose during their PLTL workshops.

Following the debriefing time, the learning specialist passed out the problem set for the week (Appendix F). Problem sets were developed by the learning specialist based on the weekly content covered by the Biology 123 instructor. Each problem set had several activities for the workshop students to engage in. The learning specialist modeled the problem-solving methods each week by having the peer leaders collaborate in small groups on the problem-solving activities much like their students should. While answers were generally not provided to the problem set activities, peer leaders were able to ask for clarification or helpful hints on any of the activities. Answers were only provided if there was an activity like a Jeopardy game in which there could be only one answer.

After the Biology 200 PLTL class each week, the peer leaders facilitated a one-hour PLTL session for a group of students of their own (between one and ten, depending on how many students attended the workshop), without the presence of the instructor or learning specialist. Leaders offered guidance and support to their own students through the thought processes of solving the same problems they themselves worked on in their class with the learning specialist and other leaders.

Peer leaders were required to keep a weekly written journal of their PLTL workshop experiences. Journal entries were submitted through the Biology 200 Blackboard site within three days of the workshop time. While journal entries varied among the leaders, peer leaders generally reflected on how their workshop went for the week. Reflections included how they thought the workshop went, what problems the students had, how the students interacted with each other and with them, etc.

In addition to the journal entries, peer leaders were required to work with a partner and develop a problem set based on the teaching and learning strategies discussed throughout the Biology 200 PLTL course. The problem set had to be a topic that had not been covered in a previous problem set or that their students had had difficulty with previously in the semester. The problem sets were then presented to the group of peer leaders in the Biology 200 PLTL class.

Throughout the Spring 2011 semester, peer leaders attended a total of 13 Biology 200 classes and ran either 11 or 12 PLTL workshops. Although 12 workshops were scheduled for each leader, a snow day and Good Friday resulted in some leaders running only 11 workshop sessions. The participants in the control group did not participate in the PLTL instructional model/training and leadership experience.

Instrument

To determine the appropriate instrument for the study, target audience, theory base, validity, reliability, length of time to administer, cost of the instrument, and time required for scoring were considered.

The critical thinking instrument used for this study was the valid and reliable California Critical Thinking Skills Test (CCTST) (Facione, 1990b) that is based on the consensus conceptualization of critical thinking as determined by the 46 experts of the Delphi panel (Facione, 1990a). The test takes approximately 45 minutes and costs $6 per test. The scoring of the test is included in the cost of each test and is completed by Insight Assessment within 20 days of receipt of the response forms. Output is in the form of a score between 0 and 34, with higher scores indicating a higher level of critical thinking.

The CCTST is a standardized, 34-item multiple choice, college level test intended for measuring the critical thinking skills of undergraduate students. Each multiple choice item is a short reading passage, followed by a question that offers 4 or 5 answer choices. The test items use everyday scenarios, and any specialized information needed to answer the question correctly is provided in the question itself (Facione, Facione, and Winterhalter, 2011**).** Because there is no specific content knowledge presumed of the test takers, the CCTST can be used with all adult populations with an 8th grade reading level or above (Facione, Facione, and Winterhalter, 2011). The score on the test is determined by the number of correct answers to the questions, and only tests in which 60 percent or more of the questions are answered are scored.

All the test items of the CCTST together provide an overall measure of critical thinking, as well as a measure of five skill descriptions: analysis and interpretation, evaluation and explanation, inference, deductive reasoning, and inductive reasoning. The scale scores of each skill are useful for guiding the development of training programs and curricula (Facione, Facione, and Winterhalter, 2011). Descriptions of each of the five skills, as provided by Insight Assessment (Facione, Facione, and Winterhalter, 2011), are given below:

<u>Analysis and interpretation</u> skills are described as skills used to closely examine ideas, to identify assumptions, reasons, and claims, and to gather detailed information from charts, graphs, diagrams, paragraphs, etc. These skills are also used when determining the precise meaning of a sentence, passage, text, idea, assertion, sign, signal, chart, etc.

<u>Evaluation and explanation</u> skills are described as skills used to assess the credibility of claims and the strength or weakness of arguments. Evaluations skills can also be applied to form

judgments about the quality of inferences, analyses, interpretations, options, opinions, beliefs, ideas, proposals, beliefs and justifications. Explanation involves providing one's reasons, methods, assumptions or rationale for one's beliefs and conclusions.

Inference skills are described as those skills used to draw conclusions based on reasons and evidence. Inferences can be skillfully drawn from a wide variety of things including information, data, beliefs, opinions, facts, conjectures, definitions, principles, images, signs, behaviors, documents, or testimony.

Deductive reasoning moves from the assumed truth of a set of beliefs or premises to a conclusion which follows of necessity. In a valid deductive argument the conclusion cannot possibly be false if the premises are all true.

Inductive reasoning is drawing warranted probabilistic inferences regarding what is most likely true or most likely not true, given the information and the context at hand. Drawing probabilistic conclusions based on key examples, evidence, data, precedents, memories, testimony, or relevant cases is inductive.

Although there is a cost to utilize this instrument, the CCTST's target audience is undergraduate college students only, it has been shown to be both valid and reliable, it requires minimal time to administer and score as compared to other assessments, and it is based on current critical thinking theory as defined by the APA Delphi panel definition of critical thinking adopted for this study (Facione, 1990a).

Instrument Reliability

The validity and reliability of the CCTST was determined through a series of four experiments that indicated that the test is an effective measure of the growth in critical thinking skills as a result of college level instruction. The experiments involved 1169 college students and 20 instructors of 45 sections of five courses and three departments and were conducted at a Western, urban state university during the 1989/1990 academic year. The first experiment compared pre-test and post-test means for two independent groups of critical thinking students. The reliability coefficient (KR-20) was .69 for the pre-test and .68 for the post-test. In the second experiment, a control group of three sections of Introduction to Philosophy showed that there was no significant difference between the two groups. The third experiment used paired pre-test/post-test scores to reveal that students who completed an approved critical thinking course did significantly better on the CCTST than those who were only beginning their critical thinking course. The final experiment involved the control group for the related pairs experiment and retained that there was no significant difference between the two groups. Concurrent validity of the CCTST is demonstrated by positive correlations to the SAT math and verbal, GPA, and Nelson-Denny reading tests (Facione, 1990c). In addition, the test lacks gender, racial or ethnic, and academic major bias (Facione, 1990d). Recommended percentile rankings for an overall score and five sub-scores on the CCTST were normalized with statistical analyses of data collected from 1673 test forms of college students enrolled in approved critical thinking courses and control group courses (Facione, 1990e).

Procedures in Instrument Administration

Participants in this study took both a pre-test and post-test measure of critical thinking; the same critical thinking test was administered at the beginning and end of the Spring 2011 semester. A paper and pencil pre-test was administered by a third party to all participants during the first week of the Spring 2011 semester. Prior to the start of the pre-test, the researcher met with the third party administrator and explained the role of administering data collection instruments and keeping them confidential in a locked office until after the grading for the Spring 2011 semester was complete.

Before the pre-test, the researcher created unique 9-digit identification numbers for participants and pre-coded each demographic survey with an identification number. In addition to the pre-coded demographic surveys, the third party administrator was provided with paper and pencil copies of the CCTST, response forms, and instructions for test takers.

During the test, only the third party administrator was present; participants were seated in a large auditorium with desks, and the auditorium was quiet. The third party administrator handed out a pre-coded demographic survey to each participant in the study and instructed the participants to use the unique 9-digit identification number to fill out the response forms for the CCTST, as well as all other data collection instruments. Instructions for the test were provided, and participants were given 45 minutes to complete the test. Those who finished before the allotted time were able to submit all the data collection instruments and quietly leave the auditorium.

Upon completion of the test, the third party administrator recorded the name of each participant and their assigned identification number. A key of the assigned identification numbers was required to be able to contact all participants at the end of the semester regarding the post-test information. All pre-test data collection instruments and the key of assigned identification numbers were kept in a locked cabinet that only the third party administrator had access to until the grading of the Spring 2011 semester was completed. Throughout the duration of the study, the researcher remained blind to which students in the Biology 200 PLTL class participated in the research.

To minimize validity threats of history, maturation, regression, and selection, a critical thinking post-test was given approximately 15 weeks later to both the treatment and control groups at the end of the Spring 2011 academic term. Using the standard notation of Campbell and Stanley (1963), a quasi-experimental approach to the study is illustrated in Figure 1 with X representing the exposure of the treatment group to the PLTL instructional model and O representing the pre-test and post-test measure of critical thinking (Creswell, 2009).

Towards the end of the Spring 2011 semester, the third party administrator contacted all participants from the control group via email and invited them to return to take the critical thinking post-test (Appendix G). Participants were offered to take the test at any time that was convenient for them during the last full week of classes, and they were told that they would be entered into a drawing for a Syracuse University Bookstore gift card if they came to complete the post-test. Participants in the treatment group were told by the BIO 200 instructor that the critical thinking post-test would be administered by a third party the last day of the Biology 200 PLTL class.

During the last full week of classes of the Spring 2011 semester, participants from the control group did not return to take the post-test. A second invitation was sent out to the participants offering a pizza party (Appendix H). For those participants who came to take the post-test, the third party administrator seated them in a private, quiet office and gave them 45 minutes to complete the paper and pencil post-test after providing instructions about the test (Appendix I). Participants were given the same unique identification number assigned at the pre-test to allow paired sample comparisons. Data collection instruments were collected and kept locked up by the third party administrator.

Treatment group participants took the critical thinking post-test during the last day of their Biology 200 PLTL class, and they were informed by the third party administrator that they would be entered into a drawing for a gift card for coming to take the post-test (Appendix J). Paper and pencil tests were given to the students, along with the previously assigned unique identification numbers. Participants were given 45 minutes to take the post-test after instructions were provided. Data collection instruments were collected and kept locked up by the third party administrator.

Upon completion of the paper and pencil critical thinking post-test, participants in both groups were asked to complete an open-ended questionnaire (Appendix K) about their perception of their critical thinking skills. This provided participants the opportunity to self-report on their critical thinking skills and reflect on why they felt their critical thinking skills improved or did not improve throughout the experimental time frame. Data collected through this questionnaire was used as a comparison to the actual results of the critical thinking test in the data analyses.

Due to the minimal number of control group participants that returned to take the post-test, the researcher contacted Insight Assessment and made arrangements for online testing for those participants who did not take the paper and pencil post-test. Because the researcher could not impact the control groups' grades in any way, the researcher was given permission by the IRB office to obtain a list of control group participants and identification numbers by the third party administrator. The researcher then contacted each participant via email and provided instructions for taking the post-test online (Appendix L), as well as their individual identification number used on the pre-test. The same version of the critical thinking test was given, and the same amount of time was allotted for the test. The online version of the CCTST, however, provided participants the opportunity to take the test anywhere and anytime that was convenient for them. Participants who took the post-test in this way were not proctored by anyone and were not able to take the open-ended questionnaire.

After the grading for the Spring 2011 semester was completed, the researcher was given all data collection instruments and identification numbers by the third party administrator. All paper and pencil versions of the CCTST, pre-test and post-test, were sent to Insight Assessment for scoring. Online versions of the test were also scored by Insight Assessment. CCTST scores were provided to the researcher through Insight Assessment's electronic testing system. Overall CCTST scores and five sub-scale scores for each individual were provided, as well as descriptive statistics for each group. A histogram of each group's overall pre-test and post-test critical thinking scores was included in the report of scores.

Data Analyses

Statistical analyses of the quantitative data associated with the CCTST were performed through a statistical software package, SPSS 19. Among the treatment group participants, a one-way repeated measures analysis of variance (RM ANOVA) was conducted to analyze overall critical thinking scores. Paired t-tests were also performed for each of the five sub-scale scores to examine differences in critical thinking skills as measured by the CCTST prior to the treatment and immediately following the PLTL training and leadership experience. To increase statistical accuracy, gender, ethnicity, class standing, major and number of science courses taken prior to and during the Spring 2011 semester were analyzed as co-variables.

Overall critical thinking scores were compared between the PLTL group and the non-PLTL group using mean, standard deviation, and two-way RM ANOVA. The two-way RM ANOVA was applied to the data because there were paired pre- and post-test scores, as well as a comparison group. Due to a non-normal distribution of data in either the pre-test or the post-test, nonparametric tests were performed on each of the five sub-scale scores.

Qualitative data obtained through the open-ended critical thinking questionnaire was analyzed by coding the responses of the participants as “perceived improvement in critical thinking skills” or “did not perceive improvement in critical thinking skills” to determine if participant self-report coincided with actual critical thinking test score data. Factors perceived to influence critical thinking skills were also coded.

Additionally, independent t-tests were conducted to compare the grade performance of the peer leaders’ students (those students in the Biology 123 course that were enrolled in the PLTL workshops) to Biology 123 students that were not enrolled in the PLTL workshops. Peer leaders’ students that attended at least nine PLTL workshops were included in the analyses because they attended 75% or more of the offered workshops. The Biology 123 students were offered the opportunity to earn a maximum number of extra credit points if they attended 10 workshops. However, due to the cancellation of school days, students who attended 9 or more workshops could meet the criterion for receiving maximum extra credit points.

Because attendance at the PLTL workshops was not mandatory, the Biology 123 students did not all attend the same number of sessions leading up to each exam given throughout the Spring 2011 term. Comparisons of individual exams could have included students who attended no PLTL workshops or very few workshops in the PLTL-treatment sample due to the randomness of student attendance. For this reason, individual exams given throughout the term were not used in the grade performance analyses. The final exam, however, was given at the end of the term after all workshop sessions had been completed and all students had attended at least 9. Final exam scores, as well as final course grades were included in grade performance analyses. Upon determination of final course grade percentages of the Biology 123 students, chi-square analysis was performed to determine any difference between the PLTL and non-PLTL groups.

Further comparisons between groups of students in the Biology 123 course were analyzed through a one-way ANOVA. Historically, the Biology 123 course was a 4-credit course that included the lab. With new curriculum changes in the Biology department, the lab is no longer a required portion of the Biology 123 course. Students can take the 1-credit Biology Lab course in addition to the Biology 123 course, or they can choose to take only the lecture without the lab. In the past, students who have decided not to take the lab affiliated with the Biology 123 course have not performed as well in the Biology 123 course. To determine if PLTL could help improve grade performance of those students who did not enroll in the lab, analyses were done to compare students not enrolled in PLTL or lab, students enrolled only in PLTL, students enrolled only in lab, and students enrolled in both PLTL and lab.

Methodological Assumptions

Quantitative analysis of the data collected in this study involved several statistical assumptions. Statistical tests assumed that the sample sizes were sufficiently large; that the data were normally distributed, although for samples of moderate or larger size the assumption of a normal population is relatively unimportant and departures from normality make little difference in conclusions derived from t-tests and ANOVA (Hays, 1981); and that the variance between groups was equal.

Within the qualitative portion of this study, it was assumed that participants accurately expressed their true perceptions of critical thinking skills and could, therefore, be used to draw conclusions from the data. While it is reasonable to assume that the expressed perceptions of participants in this study bear similarities to other undergraduate students, the qualitative data may not be generalizable to other populations.

CHAPTER 4: ANALYSES AND DISCUSSION OF FINDINGS

Overview

This chapter presents the results of statistical analyses used to answer the research questions, as outlined in Chapter 1, addressed in this study. Findings of the influence of the PLTL training and leadership experience on undergraduate peer leaders are presented for both overall critical thinking skills scores, as well as five sub-scale scores. Results of a comparison of peer leader perception and actual critical thinking skills are also presented.

Further findings are presented for analysis of the influence of the PLTL training and leadership experience on undergraduate peer leaders when compared to similar students without the PLTL training and leadership experience, as well as findings of analyses controlling for demographic factors.

Additional findings of the influence of the PLTL model on the peer leaders' students are presented with respect to grade performance. Results of analyses are reported for both final exam scores, as well as final course grades. Results of further analyses comparing PLTL/non-PLTL groups, as well as PLTL groups and lab groups are also reported. This chapter concludes with a discussion of these findings.

Analyses of Findings

Influence of PLTL on Critical Thinking Skills

Does the PLTL training and leadership experience in biology influence the critical thinking skills of undergraduate peer leaders?

Prior to the PLTL training and leadership experience, participants' critical thinking skills were measured with the CCTST as described in Chapter 3. The output from the CCTST was provided as a score between 0 and 34, with a higher score indicating a higher level of critical thinking. Individual scores for each of the five sub-scales were also provided. Recommended CCTST Categorical Cut Scores for the overall score and the sub-scale scores are provided in Table 5.

The mean pre-test score on the CCTST was 18.46 (n=37), which corresponds to a midrange total score, a score falling between the high and low cut. The CCTST scores obtained from individual participants, however, ranged from a low score of 10 to a high score of 27. According to the Recommended CCTST Categorical Cut Scores, 3% of the peer leader participants' scores indicated a low score, 92% indicated a midrange score, and 5% indicated a high score. Midrange total scores are typical of persons suitable for learning and employee development with appropriate instructional guidance, experience, and the desire to perform up to expectations (Facione, Facione, and Winterhalter, 2011).

The mean on the CCTST post-test was 18.76 (n=37), indicating an average gain of 0.30 over CCTST pre-test scores. A one-way repeated measures ANOVA was conducted to compare CCTST pre-test and post-test scores, and no significant difference was observed for critical thinking skills of undergraduate peer leaders participating in the PLTL training and leadership experience, $F(1, 36)=0.290$, $p=0.593$, power=0.082, partial eta squared=0.008.

Individual CCTST post-test scores also varied over a wide range, with the lowest score being a 12 and the highest score being a 28. The lowest scoring pre-test participant improved their score by 4 points, while the highest scoring pre-test participant decreased their score by 1 point. While 43% of the post-test participants improved their CCTST score over the pre-test, 57% of the post-test participants earned a score equal to or less than their original score on the pre-test. The distribution of CT gains is shown in Figure 2. According to the Recommended Categorical Cut Scores, 5% of the peer leader participants' scores indicated a low score, 92% indicated a midrange score, and 3% indicated a high score. Table 6 shows raw scores of the PLTL group for overall CCTST scores, while Figure 3 shows the change in critical thinking among the PLTL group on the CCTST pre- and post-treatment.

<u>Sub-Question</u>: *Does the PLTL training and leadership experience in biology influence any particular critical thinking skill tested by the CCTST (analysis and interpretation, evaluation and explanation, inference, deductive reasoning or inductive reasoning) more than another?*

Paired t-tests were conducted to compare the pre-test and post-test scores of the five critical thinking sub-scales, and no significant differences were revealed for any of the five critical thinking sub-scales: inductive reasoning, t (36) = .356, p = .724 , deductive reasoning, t (36) = -1.061, p = .296, analysis and interpretation, t (36) = .780, p = .440, inference, t (36) = -.643, p = .525, and evaluation and explanation, t (36) = -.919, p = .364. Tables 7 and 8 present the means (with standard deviations in parentheses) of the sub-scale scores. Mean pre- and post-treatment scores for each of the five critical thinking sub-scales are graphically illustrated in Figure 4.

<u>Sub-Question</u>: *Does peer leader perception of critical thinking correspond to actual CCTST results?*

Of the 37 participants in the treatment group, 36 (97%) responded to the open-ended questionnaire given after the CCTST post-test. With respect to peer leader perception of critical thinking, 62% of the peer leader participants thought they improved their critical thinking skills over the course of the Spring 2011 semester, while only 43% of the peer leaders actually improved their skills from the pre-test to the post-test (Table 9). A comparison between actual and perceived critical thinking skills was conducted by means of a chi-square analysis, x^2 (1, n=37) = 0.42, p = 0.52. The percentage of participants that actually showed improvement in critical thinking and perceived improvement in critical thinking did not differ.

Further analysis of the responses provided on the open-ended questionnaire revealed recurring themes related to participants' perception of their critical thinking skills. When asked the questions "What do you think contributed to your change in critical thinking skills?" and "How did your experience as a workshop leader influence your critical thinking skills?", about half of the participants' who perceived improvement in their critical thinking skills framed their answers in terms of working with other people. The following answers are typical of participants' responses involving working with others:

"Working with and helping random people through something I've succeeded in. Also, I've tried to think about things how others think about them."

"Working through problem sets with students and observing their way of doing things".

"The peer leader session where you help others get answers while you think about what's the best way for them to reach the answer without you telling them."

"Listening to students' answers and their reasoning behind each answer definitely influenced my critical thinking skills".

In addition to the responses related to working with others, many participants' who perceived improvement in their critical thinking skills framed their answers in terms of utilizing different approaches. Among these participants' were comments like these:

"I think leading the PLTL sessions has contributed to my improvement in critical thinking skills, as it allowed me to apply different types of thinking each week".

"By giving me different points of view in terms of approaching questions".

"Offered new ways and approaches in looking at biology".

Even some participants' who did not perceive an improvement in their critical thinking skills responded that the PLTL sessions taught them another way to approach questions and encouraged them to consider alternative ways of teaching and learning the material.

Ten of the respondents framed their answers to these questions in terms of working through the problem sets. The following responses are typical of participants' responses involving problem solving:

"I believe doing the problem sets and revisiting old material contributed positively to my critical thinking skills".

"I think that leading the students in problem sets and utilizing the strategies that we learned in class changed my critical thinking skills".

"Watching my students work thoroughly through their problem sets and discuss answers with one another made me re-think how I answer questions. Working through PLTL I was able to improve my problem solving skills".

In addition to responses framed in terms of working with others, utilizing various approaches, and working through problem sets, one participant responded that having to elicit discussion in the PLTL group contributed to improved critical thinking skills.

Other questions on the open-ended questionnaire asked peer leader participants, "how do you think you did on the critical thinking pre-test compared to the critical thinking post-test?" and "how have your critical thinking skills changed since the beginning of the semester?" Several students responded that they did better on the post-test because they had seen the questions before and had time to think about them or that they remembered the questions from the pre-test. For the same reason, other students believed that they did worse on the post-test because they simply tried to remember what they wrote the first time instead of thinking the questions through. Being tired, having too many tests this time of year, and not reading as carefully were other reasons provided by participants for not doing as well on the post-test.

In general, peer leader responses to these two questions revealed that students who reported they did worse or the same on the post-test also reported that their critical thinking skills did not change. Similarly, student responses reporting that they did better on the post-test were typically followed by responses suggesting their critical thinking skills had improved. Three peer leaders reported that they did not improve on the post-test but improved their critical thinking skills, while two peer leaders reported that they did better on the post-test but did not improve their critical thinking skills.

What differences in critical thinking skills, if any, exist, between student leaders in the PLTL instructional program and similar students without the PLTL training and leadership experience?

The mean pre-test score of the peer leaders on the CCTST was 18.46 (n=37), while the mean pre-test score of similar students without the PLTL training and leadership experience on the CCTST was 17.82 (n=17). Both groups' scores corresponded to a midrange total score. Individual scores of the treatment group participants ranged from a low score of 10 to a high score of 27, while individual scores of the control group participants ranged from a low score of 13 to a high score of 25. According to the Recommended CCTST Categorical Cut Scores, 3% of the treatment group scores and 0% of the control group scores indicated a low score, 92% of the treatment group scores and 94% of the control group scores indicated a midrange score, and 5% of the treatment group scores and 6% of the control group scores indicated a high score.

The mean post-test score of the peer leaders was 18.76 (n=37), indicating an average gain of 0.30 over CCTST pre-test scores. The mean post-test score of similar students without the PLTL training and leadership experience was 16.35 (n=17), indicating an average negative gain of 1.47. A two-way repeated measures ANOVA was conducted to compare total pre-test and post-test scores of the treatment and control groups, and no significant interaction was observed for critical thinking skills of peer leaders participating in the PLTL training and leadership experience, $F(1, 52) = 2.440$, $p=0.124$, power=0.335, partial eta squared=0.045. Table 6 shows overall raw scores for the PLTL and non-PLTL groups. The mean participant scores on the CCTST for pre- and post-treatment measurements are graphically compared in Figure 5.

Individual CCTST post-test scores of the treatment group participants ranged from a low score of 12 to a high score of 28, while individual CCTST post-test scores of the control group participants ranged from a low score of 8 to a high score of 26. The lowest scoring pre-test participant in the treatment group improved their score by 4 points, while the lowest scoring pre-test participants in the control group decreased their score by 1 and 5 points. The highest scoring pre-test participant in the treatment group decreased their score by 1 point, while the highest scoring pre-test participant in the control group scored exactly the same. 43% of the treatment group improved their CCTST score over the pre-test, and 35% of the control group improved their CCTST score over the pre-test. According to the Recommended CCTST Categorical Cut Scores, 5% of the treatment group scores and 24% of the control group scores indicated a low score, 92% of the treatment group scores and 64% of the control group scores indicated a midrange score, and 3% of the treatment group scores and 12% of the control group scores indicated a high score.

Although the total pre-test and post-test scores of the PLTL and control groups were normally distributed, there was a non-normal distribution of data in either the pre-test or the post-test of the five sub-scales of critical thinking. For this reason, nonparametric analyses of the five sub-scale scores were conducted. Friedman's chi-square test revealed no significant differences across groups for deductive reasoning, x^2 (1) = 0.556, p = 0.456; inductive reasoning, x^2(1) = 0.023, p = 0.879; analysis and interpretation, x^2 (1) = 2.632, p = 0.105; inference, x^2 (1) = 0.220, p = 0.639; and evaluation and explanation, x^2 (1) = 0.818, p = 0.366 (Tables 7 and 8).

<u>Sub-Question</u>: *How does peer leader perception of critical thinking compare to control group participants' perception of critical thinking?*

With a small starting sample of non-PLTL leaders, only two participants completed the questionnaire related to perception. Both non-PLTL leaders perceived that their critical thinking skills did not really improve, however, both participants' critical thinking skills showed a slight improvement from the pre-test to the post-test. Although 62% of the peer leader participants thought they showed an improvement in critical thinking skills while only 43% actually did, with only two participants in the non-PLTL leader group, accurate comparisons could not be made between groups.

Does the PLTL training and leadership experience in biology influence critical thinking skills of undergraduate peer leaders, controlling for the effects of demographic variables?

Sub-Question: Which variables have the greatest impact on critical thinking gains?

A series of one-way repeated measures of ANOVA were conducted with each demographic factor as a co-variable. Class standing, gender, ethnicity, major, number of science courses taken prior to the Spring 2011 term, and number of science courses taken during the Spring 2011 term were not indicators of critical thinking gains of peer leaders.

Additional Findings

Influence of PLTL on Leaders' Students

Grade performance analyses were performed on students who attended nine or more PLTL workshop sessions run by the peer leaders throughout the Spring 2011 term. Grade performance of the students in the PLTL workshops was analyzed using final exam scores in the Biology 123 course, final course grades in the Biology 123 course, as well as percent of students receiving an A, B, or C grade (%ABC) and percent of students receiving a D or F grade (%DF) in the Biology 123 course. The final course grades were translated such that a grade of A corresponded to 89.5 to 100, B corresponded to 79.5 to 89.49, C corresponded to 67.5 to 79.49, D corresponded to 59.4 to 67.49, and F corresponded to less than 59.4.

The mean Biology 123 final exam score of PLTL students (n=136) was 79.38 (SD = .10), while the mean Biology 123 final exam score of non-PLTL students (n=247) was 74.89 (SD =.19) (Table 10). While the final exam scores ranged from a low grade of F to a high grade of A, both groups' mean scores corresponded to a grade of C. An independent t-test was conducted to compare the final exam scores of the PLTL and non-PLTL students, and the mean performance of the PLTL students was significantly higher than that of the non-PLTL students, t (383) = -2.538, p=0.012[1].

PLTL students also earned significantly higher final course grades compared with non-PLTL students, t (383) = -2.962, p = .003[1]. Of the 383 students with final course grades (Table 10), PLTL students earned an average grade of 80.15 (SD = 8.64), whereas non-PLTL students earned an average grade of 75.75 (SD = 16.08). While the final course grades revealed a wide range of scores spanning from a low of F to a high of A for both groups, the final course grades obtained by the PLTL students corresponded to a B and the final course grades obtained by the non-PLTL students corresponded to a C. The mean final exam scores and final course grades of PLTL and non-PLTL groups are graphically compared in Figure 6.

Chi-square analysis ($\mathbf{x^2}$ = 11.513, p = 0.021) of final course grade percentages indicated that a significant difference was observed for grade performance when comparing PLTL students to non-PLTL students. Almost 93% of the PLTL students (n= 136) received an A, B, or C and only 7% received a D or F compared with about 82% of non-PLTL students (n=247) who

[1] The grade averages reported here do not include those of students who withdrew from the course. Therefore, the average grades may appear somewhat high, and failure rates reported later may appear artificially low. Other studies have grouped students who withdrew with those who have earned Ds or Fs, however, even high achieving students withdraw for strategic purposes unrelated to success in the course. Also, because only those students who attended a minimum of 9 PLTL sessions were considered to have participated, those who withdrew from the course before the 10th week of the semester could not be included in the analyses.

received an A, B, or C and 18% who received a D or F (Table 11). A comparison of grade percentages for PLTL and non-PLTL groups is provided in Figure 7.

Further analysis of final course grade percentages was conducted to compare a group of non-PLTL and non-lab students, a group of PLTL only students, a group of lab only students, and a group of PLTL and lab students. A one-way ANOVA revealed that there were significant differences between groups, $F(3, 379) = 17.893$, $p = 0.000$. A follow up Tukey HSD analysis revealed that PLTL only students, lab only students, and PLTL and lab students all had significantly higher final grade percentages than the non-PLTL and non-lab students.

When PLTL only students were compared to lab only students, there was no significant difference found between the groups. Mean final course grades by group are reported in Table 12. The average final grade percentage for PLTL only students was 78.09 compared to 79.50 for the lab only students. While the students who were enrolled in both PLTL and lab earned the highest final grade percentages, there was no significant difference found between those students and students enrolled in PLTL only or lab only. The average final grade percentage for the students enrolled in both PLTL and lab was 80.64 compared to 78.09 and 79.50 for students enrolled in PLTL only or lab only respectively. Comparisons of mean final course grades are graphically illustrated in Figure 8 and Figure 9.

Discussion

The purpose of this study was to investigate whether the PLTL training and leadership experience in Introductory Biology could promote critical thinking in undergraduate peer leaders. The PLTL training and leadership experience provided a collaborative instructional opportunity for peer leaders to interact with faculty and peers while applying learning theory and working through problems related to the content of an introductory biology course. Quantitative analyses demonstrated the impact of the PLTL training and leadership experience on the critical thinking skills of peer leaders, while qualitative data provided insight into peer leader perception of critical thinking skills.

Results of the total pre- and post-treatment measurements of the CCTST indicated no statistically significant difference in peer leaders' critical thinking skills. Additionally, results of the five sub-scales of critical thinking as measured by the CCTST indicated no significant differences in peer leaders' critical thinking skills.

The peer leaders did not have a positive significant improvement in their critical thinking skills, rather their average from pre- to post-test increased slightly. The mean score of the national comparison group on the CCTST was 16.8 (Facione, Facione, and Winterhalter, 2011), while the mean pre-test score of the peer leaders in this study was 18.46. This illustrates that on average, the peer leaders in this study already had good critical thinking skills. With most of the peer leaders being juniors and many being science majors, many had taken a large number of science courses prior to the PLTL training and leadership experience. As discussed in the previous literature review, the number of science courses taken by an individual can influence critical thinking skills; which could be a contributing factor to why this particular group of peer leaders had an average greater than the national comparison group. However, even with a higher starting mean than the national average of the comparison group, according to the CCTST manual, the peer leaders should have been capable of benefiting from an educational model such as PLTL because their score fell in the midrange of total scores (Facione, Facione, and Winterhalter, 2011).

Although the mean pre-test score fell within the midrange of scores on the CCTST and is indicative of persons suitable for learning development with appropriate instructional guidance, peer leader commitment throughout the PLTL training and leadership experience could have played an important role in critical thinking gains. With 37 peer leaders, there was likely to be a high level of variance in the PLTL leadership and training experience. While some leaders may have been actively engaged in class discussion, writing tasks, and interaction with faculty and peers throughout the Biology 200 course and problem solving sessions, others may not have integrated these factors that could potentially influence their critical thinking skills into their experience as well. Some peer leaders may have taken on the role of a facilitator in the workshops without actually participating themselves. One peer leaders' response that his participation as a PLTL leader did not influence his critical thinking skills much "because the students did most of the thinking, not me" suggests a lack of active participation with the students in the problem solving session. Other peer leaders may have devoted time to discussing study tips or review of material for exams instead of completing the problem sets each week, or they may have simply answered the questions in the problem sets without implementing the specific instructions provided for each group of problems that incorporated the factors that have been shown to improve critical thinking skills. This could explain why some peer leaders improved their critical thinking skills while others did not.

In addition to the high variance in peer leader commitment to the PLTL model, peer leaders' dispositions to utilize critical thinking skills could have contributed to the lack of significant improvement in critical thinking skills between the pre- and post-test measurement. As discussed in the previous literature review, disposition refers to the consistent internal motivation to engage problems and make decisions by using critical thinking (Facione, 2000).

While some peer leaders may have improved their critical thinking skills during the PLTL training and leadership experience, that improvement may not have been reflected in their post-treatment CCTST score if they were not willing to utilize those skills.

Lack of motivation or willingness to engage in the problems on the post-treatment CCTST with sufficient effort may have been the result of when the test was administered. Several students commented on their open-ended questionnaire that there were too many tests at that time of the semester or that they were too tired to take the test when given. Others commented that they simply did not read the questions on the post-test as carefully as they read the questions on the pre-test or that they just tried to remember their previous answers. These reasons suggest that some participants may not have been utilizing their critical thinking skills to the best of their ability and could potentially explain the lack of improvement or even negative critical thinking gains achieved by some of the peer leaders.

Interestingly, although only 43% of the peer leaders improved their critical thinking skills, 62% of the peer leaders perceived that their critical thinking skills improved. Previous research demonstrated that peer leaders perceived benefits from the PLTL training and leadership experience such as increased content knowledge, improved people skills, improved confidence and improved cognitive skills (Gafney and Varma-Nelson, 2002, 2007; Johnson and Loui, 2009; Micari, Streitwieser, and Light, 2006; Tenney and Houck, 2004). These data confirm previous findings that students perceive benefits from the PLTL experience by demonstrating that peer leaders also perceive improvement in their critical thinking skills. However, the students' reported perceptions do not appear to correspond to measured results in all cases.

A greater percentage of perceived improvement compared with actual improvement may have been attributed to a lack of understanding of the definition of critical thinking by the peer leaders. While peer leaders perceived improvement in their critical thinking skills, they may have defined those skills in relation to how they did on the CCTST or as improved communication skills, collaborative skills, content knowledge, etc. However, with regard to factors that may influence critical thinking skills as identified through the previous literature review, peer leaders identified at least some of those factors as having influenced their critical thinking skills. While the most commonly cited reason for improved critical thinking skills was working with peers, many others cited working through the problem sets as influential in their change in critical thinking skills from the pre- to the post-treatment measure of critical thinking. Discussion was also cited as a contributing factor to improved critical thinking skills.

When peer leaders were compared to similar students who did not participate in the PLTL training and leadership experience, results of the total pre- and post-treatment measurements of the CCTST, as well as the five sub-scales of critical thinking, indicated no significant differences between the groups. While a small gain in the mean overall critical thinking skills was shown for the peer leaders, a trend of negative gains in the mean overall critical thinking skills was seen for similar students who did not participate in the PLTL training and leadership experience. Just as the peer leader participants' average, the average critical thinking score of the non-peer leaders was above the mean for the national comparison group for the pre-test, however, the mean on the post-test score dropped below the national comparison group mean. While there was no attrition in the number of participants in the treatment group, there was greater than a 50% attrition rate in the control group of the study. With such high attrition, the sample size of the control group was very limited. Within the small number of participants in the control group, several also had fairly large negative gains in critical thinking implying that the test may not have been taken with sufficient effort. These reasons suggest why the control group may have seen negative critical thinking gains from pre- to post-measurements.

When comparing peer leader perception to non-peer leader perception of critical thinking skills, 62% of peer leaders perceived improvement in their critical thinking skills compared to 0% of the non-peer leaders. This suggests that participation in the PLTL training and leadership experience can influence how students perceive their critical thinking skills. While it is unclear which aspects of the PLTL training and leadership experience influenced this perception, it is reasonable to suspect that the collaborative nature of working through problem sets with peers supported their perception of improved critical thinking skills. However, only two control group participants completed the open-ended questionnaire, so accurate comparisons between the two groups were not possible.

Demographic factors did not appear to be indicators of critical thinking skills or gains therein. Within the peer leader group, the academic major of the participants was the only demographic variable that even approached significance. No significant differences in critical thinking skills were found between genders, class standing, ethnicity, or number of science courses during and prior to the Spring 2011 academic term.

While the peer leader data suggests that participation in the PLTL training and leadership experience does not have a significant positive influence on peer leaders' critical thinking skills, grade performance data of peer leaders' students confirm previous findings that the PLTL model is effective for students in the workshops (Gafney, 2001a; Hockings, DeAngelis, and Frey, 2008; Quitadamo, Brahler, and Crouch, 2009; Tenney and Houck, 2003; Tien, Roth, and Kampmeier, 2002). The results of grade performance analyses on the final exam and final course grade indicate significantly higher grades for the peer leaders' students when compared to non-PLTL students. Furthermore, grade performance analyses comparing various groups in introductory biology suggest that PLTL can be an effective model for improving the grade performance of those students who choose not to take the lab course affiliated with the second semester of introductory biology.

On average, PLTL students earned at least 1/3 of a letter grade higher on the final exam and final course grade when compared to non-PLTL students. In addition, the %ABC was significantly higher for PLTL students than non-PLTL students. These findings are consistent with previous findings in chemistry courses (Gafney, 2001a; Hockings, DeAngelis and Frey, 2008; Tien, Roth and Kampmeier, 2002). While higher grades do not necessarily prove greater conceptual understanding by the students (Tenney and Houck, 2003), they are suggestive of improved understanding since all the exams in the course are concept-based (J. Wiles, personal communication, January 2011).

PLTL students not enrolled in the lab also performed in the same grade range as those students who were enrolled in the lab course. This finding suggests that PLTL can be a means of providing an active learning environment for those students who choose not to enroll in the lab portion of introductory biology, and therefore, are less likely to be exposed to an active learning environment that the lab experience provides. With regard to the problem of providing students in large lectures an active learning environment, it is possible that PLTL can help shift them from an instructor-centered mode of learning to a student-centered mode of learning. PLTL can provide a learning environment that involves students in actively constructing their own understanding of scientific concepts.

Although critical thinking skills of peer leaders did not have a significant positive improvement, the results of this study seem to indicate that peer leaders view the PLTL training and leadership experience as a positive influence on their critical thinking skills and that the students within their workshops benefit from the PLTL model. None of the participants in this study, no matter how much or how little they improved their critical thinking skills, perceived the PLTL training and leadership experience to affect them negatively. Even if they thought it did not improve their critical thinking skills, several leaders reported that other skills improved, including new ways of approaching problems, communication, increased knowledge, and increased confidence. This confirms previous findings (Gafney and Varma-Nelson, 2002; Gafney and Varma-Nelson, 2007; Johnson and Loui, 2009; Micari, Streitwieser and Light, 2006; Tenney and Houck, 2004) and suggests that the PLTL training and leadership experience is of benefit to the peer leaders and their students, even if it does not significantly improve critical thinking skills. With the implementation of the PLTL model for the first time and with no prior studies done on the influence of PLTL on peer leaders' critical thinking skills, it is premature to conclude that PLTL cannot promote critical thinking in undergraduate biology peer leaders. Although Preszler (2009) was not studying critical thinking, he found that refinements of the workshop activities that occurred between the first and third workshop semesters increased the impact of the workshops on student learning, bringing the learning up beyond the levels seen in pre-workshop semesters. Similarly, refinements in the implementation of the PLTL training and leadership experience could lead to improved critical thinking skills of the peer leaders.

A major implication of this study is the impact of the PLTL approach on the concern of shifting students from the traditional instructor-centered paradigm to a student-centered paradigm (Tien, Roth, and Kampmeier, 2002). The PLTL training and leadership experience is important in educating peer leaders about how to help students actively construct their own understanding of scientific concepts. As the peer leaders facilitate PLTL workshops, they serve as role models to the students of how to utilize various ways of thinking and problem-solving techniques. This teaches the student what a student-centered classroom should look like. As students and peer leaders go on in their academic careers, they may be presented with teaching and leadership opportunities, and exposure to the student-centered PLTL model provided both peer leaders and their students with an alternative pedagogical approach to the traditional instructor-centered paradigm.

Another implication of this study is the potential impact of the PLTL model on retention of students in the sciences. As discussed in the literature review, many studies found that the PLTL model resulted in improved retention of students in introductory level science courses (Hockings, DeAngelis, and Frey, 2008; Stewart, Amar, and Bruce, 2007; Tien, Roth, and Kampmeier, 2002; Wamser, 2006). Retaining students in these introductory, “gatekeeper” science courses is necessary for retaining students in the sciences. In two programs designed to increase retention of female and underrepresented minorities, Monte, Sleeman, and Hein (2007) found a second benefit; the retention of the peer mentors was improved. Attracting talented undergraduate students to become peer leaders in a PLTL instructional model may also lead to improved retention of the peer leaders, in addition to improved retention of their students.

Although the focus of this study was not on retention of the peer leaders, there was an overall peer leader retention rate of 100% throughout the training and leadership experience. As illustrated by the participant demographics, peer leaders included males and females, as well as underrepresented minorities. Longitudinal studies of the long-term effects of the PLTL instructional model on retention of students in the sciences should be conducted.

In conclusion, the PLTL training and leadership experience appears to be an effective means of bringing about change in large, undergraduate science courses. The experience is a financially feasible way of equipping undergraduate peer leaders to help students take ownership of their own learning, while providing working relationships among peer leaders and faculty. Additionally, the experience has the potential to improve long-term retention of peer leaders and their students in the sciences.

CHAPTER 5: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Background

A review of the previous literature on peer-led team learning revealed that the PLTL model has been shown to be effective for students in grade performance, retention in the course, attitudes, conceptual reasoning, and critical thinking. However, little research has been devoted to the potential benefits of the peer leaders. Of the studies that have reported on benefits to the peer leaders, most relied on anecdotal evidence, student self-report, or superficial analysis of content gains. Additionally, there were few studies conducted in undergraduate biology courses, and there were no studies that evaluated the effect of the PLTL model on the critical thinking skills of undergraduate, biology peer leaders.

This study attempted to narrow these gaps in the literature by measuring changes in undergraduate biology peer leaders' critical thinking skills after a treatment that incorporated many of the factors identified as potentially influencing critical thinking skills. Student perceptions of critical thinking skills were also explored.

Purpose

The purpose of this study was to explore what influence the PLTL training and leadership experience may have on peer leaders' critical thinking skills in the context of an Introductory Biology course at a private, research university in the Northeastern United States. Based on the role of the peer leader and influences thought to improve critical thinking skills, the working premise of this study was that participating as a PLTL peer leader should promote critical thinking gains.

Research Questions

1. Does the PLTL training and leadership experience in biology influence the critical thinking skills of undergraduate peer leaders?

   Sub-Question: Does the PLTL training and leadership experience in biology influence any particular critical thinking skill tested by the CCTST (analysis and interpretation, evaluation and explanation, inference, deductive reasoning or inductive reasoning) more than another?

   Sub-Question: Does peer leader perception of critical thinking correspond to actual CCTST results?

2. What differences in critical thinking skills, if any, exist, between student leaders in the PLTL instructional program and similar students without the PLTL training and leadership experience?

   Sub-Question: How does peer leader perception of critical thinking compare to control group participants' perception of critical thinking?

3. Does the PLTL training and leadership experience in biology influence critical thinking skills of undergraduate peer leaders, controlling for the effects of demographic variables?

   Sub-Question: Which variables have the greatest impact on critical thinking gains?

Methods and Procedures

Data were collected in the context of an Introductory Biology course at a private, four-year, research institution in the Northeastern United States. Procedures in participant treatment, instrumentation, and data analyses are summarized in the following sections.

Treatment

The treatment involved the training and leadership experience in which participants were involved in through a special topics course. The treatment components were contained in Biology 200: Peer-Led Team Learning-A Leadership Experience. The course was designed after the PLTL model, and requirements included many of the factors identified in the literature as potentially influencing critical thinking. The PLTL course provided peer leaders the opportunity to interact with faculty, interact with peers, write journal entries, and review biology content through class discussion and problem solving.

Instrumentation

The instrument used to measure changes in participants' critical thinking skills was the valid and reliable CCTST (Facione, 1990b); a college level test that consists of 34 multiple choice questions. Participants were asked to choose the correct answer to a question based on a short reading passage provided. Output was provided in the form of a score between 0 and 34, and additional scores of the five sub-scales of critical thinking (analysis and interpretation, evaluation and explanation, inference, deductive reasoning, and inductive reasoning) were also provided.

Qualitative data were collected through an open-ended questionnaire given after the treatment.

Data Analyses

Statistical analyses of the quantitative data associated with the CCTST, as well as the quantitative data associated with the peer leaders' students were performed using SPSS. Qualitative data was analyzed through the process of coding (Bogdan and Biklen, 1998).

Selected Findings

The mean pre-test score of the peer leaders on the CCTST was 18.46 (n=37), which corresponds to a midrange total score, a score falling between the high and low cut. The CCTST scores obtained from individual participants, however, ranged from a low score of 10 to a high score of 27. According to the Recommended CCTST Categorical Cut Scores, 3% of the peer leader participants' scores indicated a low score, 92% indicated a midrange score, and 5% indicated a high score.

The mean on the CCTST post-test was 18.76 (n=37), indicating an average gain of 0.30 over CCTST pre-test scores. A one-way repeated measures ANOVA was conducted to compare CCTST pre-test and post-test scores, and no significant difference was observed for critical thinking skills of undergraduate peer leaders participating in the PLTL training and leadership experience, $F(1, 36)=0.290$, $p=0.593$, power=0.082, partial eta squared=0.008.

Individual CCTST post-test scores also varied over a wide range, with the lowest score being a 12 and the highest score being a 28. The lowest scoring pre-test participant improved their score by 4 points, while the highest scoring pre-test participant decreased their score by 1 point. While 43% of the post-test participants improved their CCTST score over the pre-test, 57% of the post-test participants earned a score equal to or less than their original score on the pre-test. According to the Recommended Categorical Cut Scores, 5% of the peer leader participants' scores indicated a low score, 92% indicated a midrange score, and 3% indicated a high score. A comparison of mean total CCTST scores is illustrated in Figure 3.

Paired t-tests were conducted to compare the pre-test and post-test scores of the five critical thinking sub-scales, and no significant differences were revealed for any of the five critical thinking sub-scales: inductive reasoning, t (36) = .356, p = .724 , deductive reasoning, t (36) = -1.061, p = .296, analysis and interpretation, t (36) = .780, p = .440, inference, t (36) = -.643, p = .525, and evaluation and explanation, t (36) = -.919, p = .364. Pre- and post-treatment scores for each of the five critical thinking sub-scales are graphically illustrated in Figure 4.

With respect to peer leader perception of critical thinking, 62% of the peer leader participants thought they improved their critical thinking skills over the course of the Spring 2011 semester, while only 43% of the peer leaders actually improved their skills from the pre-test to the post-test (Table 9). Further analysis of the responses provided on the open-ended questionnaire revealed that many participants perceived their critical thinking skills to have improved because of working with others or utilizing various approaches to thinking through problems. Other students thought they improved because of remembering the pre-test questions.

When comparing peer leaders to similar students that did not participate in the PLTL training and leadership experience, the mean pre-test score of the peer leaders on the CCTST was 18.46 (n=37) and the mean pre-test score of similar students without the PLTL training and leadership experience on the CCTST was 17.82 (n=17). Both groups' scores corresponded to a midrange total score. Individual scores of the treatment group participants ranged from a low score of 10 to a high score of 27, while individual scores of the control group participants ranged from a low score of 13 to a high score of 25. According to the Recommended CCTST Categorical Cut Scores, 3% of the treatment group scores and 0% of the control group scores indicated a low score, 92% of the treatment group scores and 94% of the control group scores indicated a midrange score, and 5% of the treatment group scores and 6% of the control group scores indicated a high score.

The mean post-test score of the peer leaders was 18.76 (n=37), indicating an average gain of 0.30 over CCTST pre-test scores. The mean post-test score of similar students without the PLTL training and leadership experience was 16.35 (n=17), indicating an average negative gain of 1.47. A two-way repeated measures ANOVA revealed that no significant interaction was observed for critical thinking skills of peer leaders participating in the PLTL training and leadership experience, $F(1, 52) = 2.440$, $p = 0.124$, power=0.335, partial eta squared=0.045. Table 6 shows overall raw scores for the PLTL and non-PLTL groups. The mean participant scores on the CCTST pre- and post- treatment are graphically compared in Figure 5.

Individual CCTST post-test scores of the treatment group participants ranged from a low score of 12 to a high score of 28, while individual CCTST post-test scores of the control group participants ranged from a low score of 8 to a high score of 26. The lowest scoring pre-test participant in the treatment group improved their score by 4 points, while the lowest scoring pre-test participants in the control group decreased their score by 1 and 5 points. The highest scoring pre-test participant in the treatment group decreased their score by 1 point, while the highest scoring pre-test participant in the control group scored exactly the same. 43% of the treatment group improved their CCTST score over the pre-test, and 35% of the control group improved their CCTST score over the pre-test. According to the Recommended CCTST Categorical Cut Scores, 5% of the treatment group scores and 24% of the control group scores indicated a low score, 92% of the treatment group scores and 64% of the control group scores indicated a midrange score, and 3% of the treatment group scores and 12% of the control group scores indicated a high score.

Friedman's chi-square test revealed no significant differences across groups for deductive reasoning, x^2 (1) = 0.556, p = 0.456; inductive reasoning, x^2(1) = 0.023, p = 0.879; analysis and interpretation, x^2 (1) = 2.632, p = 0.105; inference, x^2 (1) = 0.220, p = 0.639; and evaluation and explanation, x^2 (1) = 0.818, p = 0.366 (Tables 7 and 8).

A series of one-way repeated measures of ANOVA revealed that class standing, gender, ethnicity, major, number of science courses taken prior to the Spring 2011 term, and number of science courses taken during the Spring 2011 term were not indicators of critical thinking gains of peer leaders.

Additionally, grade performance analyses conducted on the peer leaders' students revealed that PLTL students earned significantly higher grades than non-PLTL students on the final exam (t (383) = -2.538, p=0.012) and final course grade (t (383) = -2.962, p = .003). The mean final exam scores and final course grades of PLTL and non-PLTL groups are graphically compared in Figure 6.

Chi-square analysis **(x^2** = 11.513, p = 0.021) of final course grade percentages indicated that a significant difference was observed for grade performance when comparing PLTL students to non-PLTL students. Almost 93% of the PLTL students (n= 136) received an A, B, or C and only 7% received a D or F compared with about 82% of non-PLTL students (n=247) who received an A, B, or C and 18% who received a D or F (Table 11). A comparison of grade percentages for PLTL and non-PLTL groups is provided in Figure 7.

Further analysis of final course grade percentages was conducted to compare a group of non-PLTL and non-lab students, a group of PLTL only students, a group of lab only students, and a group of PLTL and lab students. A one-way ANOVA revealed that there were significant differences between groups, $F(3, 379) = 17.893$, $p = 0.000$. A follow up Tukey HSD analysis revealed that peer leaders' students enrolled in PLTL performed significantly higher than students not enrolled in Biology Lab, and no significant difference was found between PLTL students not enrolled in Biology Lab and students enrolled in Biology Lab. Comparisons of mean final course grades are illustrated in Figure 8 and Figure 9.

Conclusions

The data collected from this study do not support the hypothesis that participation in the PLTL training and leadership experience that incorporated various factors thought to influence critical thinking skills has a positive significant influence on peer leaders' critical thinking skills. However, they do confirm previous findings that the PLTL model is an effective model for the peer leaders' students. Peer leader self-report also confirmed that peer interaction, solving problems, and discussion are factors that potentially influence their critical thinking skills.

While peer leaders' critical thinking skills may not improve, the peer leader training and leadership experience has potentially far reaching implications in science education. Many peer leaders and their students may go on to become teaching assistants or instructors during their academic career, and exposure to the student-centered PLTL model provided peer leaders with an alternative pedagogical approach to the traditional instructor-centered paradigm.

Recommendations for Future Research

Because there have been no other studies on the effectiveness of PLTL on the critical thinking skills of peer leaders, it was not possible to compare the findings of this study to historical findings. Further studies of the influence of PLTL on critical thinking skills are therefore recommended.

The findings of this study would be greatly improved by further research that incorporated a larger sample size and greater control of variables. It is recommended that similar studies be carried out not only with a larger sample size, but also by collection of data from various institutions including two year and four year, private and public, and research and non-research institutions.

Because of the high degree of variance possible in the peer leaders' workshop sessions, studies evaluating critical thinking dispositions in addition to critical thinking skills are recommended. While students may have the ability to think critically, they may choose not to exercise those abilities. Disposition could potentially influence whether or not critical thinking gains are observed in the peer leaders.

Additionally, further studies should explore other potential benefits of the PLTL model for peer leaders. This investigation only explored the influence of the PLTL model on critical thinking skills. Other benefits to the peer leaders, such as content knowledge gain, retention, and communication or collaborative skills should also be investigated.

Appendix A

Recruitment Email

Congratulations!

If you have received this message, you were among the top scoring students for Biology 123 at Syracuse University during the past two years. Your excellent performance has afforded you an opportunity to engage in an experience that we hope will be of great benefit to you as well as to your undergraduate peers who will be taking Introductory Biology this Spring semester.

You are cordially invited to attend an organizational meeting at ______ o'clock on mm/dd/year in ________ auditorium where information will be provided regarding an opportunity to earn valuable leadership experience that will be reflected on your transcript and/or to participate in an important research project related to teaching and learning in Introductory Biology.

We hope that you will be interested in taking advantage of these opportunities, and we look forward to sharing more with you at the organizational meeting. If you have questions about the meeting time or what participation may involve, please contact Julia Snyder at jjseymou@syr.edu.

Again, congratulations on your success!

Sincerely,

Professor Jason R. Wiles
Department of Biology
Syracuse University
107 College Place
Syracuse, NY 13244
jwiles01@syr.edu
(315) 443-3193

Julia Snyder, Ph.D. Candidate
Department of Science Teaching
Syracuse University
101 Heroy Geology Laboratories
Syracuse, NY 13244
jjseymou@syr.edu
(315) 559-6000

Appendix B

Consent Letter

Peer-Led Team Learning in Introductory Biology: Effects on Critical Thinking Skills

My name is Julia Snyder, and I am a doctoral student in College Science Teaching at Syracuse University. I am inviting you to participate in a research study. Involvement in the study is voluntary, so you may choose to participate or not. This sheet will explain the study to you, and please feel free to ask questions about the research if you have any. I will be happy to explain anything in detail if you wish.

I am interested in learning more about the Peer-Led Team Learning (PLTL) instructional model and its effect on undergraduate biology students' critical thinking skills. You will be asked to fill out a demographic survey and then take a critical thinking skills test at the beginning of the Spring 2011 academic term. You will then be asked to take another critical thinking skills test and fill out an open-ended questionnaire about your critical thinking skills at the end of the Spring 2011 academic term. This will take approximately 1-2 hours each. All information will be confidential. A confidential number will be assigned to your responses, and only a non-instructor/researcher third party will have the key to indicate which number belongs to which participant.

The benefit of this research is that you will be helping me to understand the potential effect of PLTL leadership experience on critical thinking skills. This information should help to determine if the PLTL instructional model is a useful model to implement in Introductory Biology so undergraduate students have a leadership opportunity that can help improve critical thinking skills. By taking part in the research, you may determine if your critical thinking skills improve over the course of an academic term.
The risks to you of participating in this study are expected to be minimal. There may be the risk of feeling anxious or nervous about taking tests. This risk will be minimized by the fact that your test scores in no way affect your GPA and will not be used for any reason other than statistical analysis to see if PLTL leadership can improve critical thinking.

If you do not want to take part, you have the right to refuse to take part without penalty. If you decide to take part and later no longer wish to continue, you have the right to withdraw from the study at any time, without penalty.

If you have any questions, concerns, or complaints about the research, contact Jason Wiles at 315-443-3193 or Julia Snyder at 315-559-6000. If you have any questions about your rights as a research participant, you have questions, concerns, or complaints you wish to address to someone other than the investigator, or if you cannot reach the investigator, contact the Syracuse University Institutional Review Board at 315-443-3013.

All of my questions have been answered, I am over the age of 18, and I wish to participate in this research study. I have received a copy of this consent form.

Signature of Participant Date

Printed Name of Participant

Signature of Researcher Date

Printed Name of Researcher

Appendix C

Demographic Survey

Identification Number___________________

Demographic Survey

Gender:

- ☐ Male
- ☐ Female

Class Standing:

- ☐ Freshman
- ☐ Sophomore
- ☐ Junior
- ☐ Senior

Ethnic Group:

- ☐ American Indian/Alaskan Native
- ☐ Asian
- ☐ Black or African American
- ☐ Hispanic/Latino
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Major: _____________________________________

Number of science courses you have completed prior to the Spring 2011 academic term:

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ More than 6

Number of science courses you will be taking in the Spring 2011 academic term:

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ More than 6

Appendix D

BIO 200 Course Syllabus

Syracuse University

BIO 200: Peer-Led Team Learning Leadership Experience

Tuesday 2:00-2:55 pm

Instructor: Julia Snyder
jjseymou@syr.edu
315-559-6000

Course Description: A 2-credit course that relates educational research literature on students and learning to classroom applications in problem solving activities. Students are prepared to be peer leaders of a small, problem-solving group of students. Peer leaders will be responsible for holding a 1-hr problem solving session each week and keep record of attendance for their group sessions.

Goal: To provide training and support for peer leaders of Biology Workshop sessions.

Text: Peer-Led Team Learning- A Handbook for Team Leaders will be provided, but MUST BE RETURNED AT THE END OF SEMESTER. Additional readings will be distributed via Blackboard.

Grading:

1. Class attendance and participation (50% or 250 points)
2. Weekly journal (25% or 125 points)-Each week, you will reflect on what your workshop was like (Ex. What you did, how your students responded, how the problems worked, what went well, what could have gone better, how your students interacted with you and each other, etc.).
3. Project (25% or 125 points)-The project will be done with a partner. Using various teaching and learning strategies discussed throughout the semester, you will design a problem set related to a topic not covered during the semester. You will then present your problem set to a group of peers.

Total: (100% or 500 points)

Grading Scale (percentages):

92.5-100	A	77.0-79.49	C+
89.5-92.49	A-	72.5-76.99	C
86.5-89.49	B+	69.5-72.49	C-
82.5-86.49	B	59.5-69.49	D
79.5-82.49	B-	0-59.49	F

Attendance Policy: Attendance in class and Workshops is required.
During class each week, peer leaders will work with the instructor to discuss various learning techniques and engage in problem-solving sets that will be done in Workshop sessions. For this reason, it is imperative that you do NOT miss class. However, I recognize that absences may occur for various reasons. If you must miss class or a Workshop session, you must contact me as soon as possible so that I can make other arrangements for your Workshop session if necessary.

1. Absence from class or a Workshop session due to an ACCEPTED DOCUMENTED REASON* will not count against the student. The total number of points available will be adjusted and the final percentage will be calculated accordingly.
2. Any absence for reasons other than an ACCEPTED DOCUMENTED REASON will be recorded as a zero and will count in the final calculation of grades.

*****Students who are absent for more than 4 classes and/or Workshop sessions during the semester FOR ANY REASON cannot receive a passing grade in Bio 200***.**

*****ACCEPTED DOCUMENTED REASONS:

1. ILLNESS: An absence due to illness requires some written confirmation that the student was seen at a hospital or doctor's office at the time specified.
2. DEATH IN THE FAMILY: An absence due to the death of a relative requires the confirmation of the funeral or memorial event via the presentation of a memorial card, newspaper obituary/notice, or link to online article. Students in this situation deserve our full sympathy and accommodation. Regrettably, however, students have been dishonest about this type of situation in the past and we must therefore require such documentation.
3. RELIGIOUS OBSERVANCE: An absence due to observance of religious events that are not listed as officially recognized university holidays require 7 days advance notice (Syracuse University does not recognize travel time as part of religious observance).

ACADEMIC INTEGRITY STATEMENT
(From SU Office of Academic Integrity)

The Syracuse University Academic Integrity Policy holds students accountable for the integrity of the work they submit. Students should be familiar with the Policy and know that it is their responsibility to learn about instructor and general academic expectations with regard to proper citation of sources in written work. The policy also governs the integrity of work submitted in exams and assignments as well as the veracity of signatures on attendance sheets and other verifications of participation in class activities. Serious sanctions can result from academic dishonesty of any sort. For more information and the complete policy, see: http://academicintegrity.syr.edu.

Students with Disabilities
(as per Vice Chancellor Eric Spina, August 2008)

Students who are in need of disability-related academic accommodations must register with the Office of Disability Services (ODS), 804 University Avenue, Room 309, 315-443-4498.

Students with authorized disability-related accommodations should provide a current Accommodation Authorization Letter from ODS to the instructor and review those accommodations with the instructor. Accommodations, such as exam administration, are not provided retroactively; therefore, planning for accommodations as early as possible is necessary. For further information, see the ODS website, http://disabilityservices.syr.edu/.

Course Schedule:

Week of	**Topic**
January 24	Role of a peer leader; Photosynthesis and respiration problems
January 31	Getting a group started; Plant reproduction, growth and development problems
February 7	Student Development; Animal structure problems
February 14	Learning Styles; Animal protection, support and movement problems
February 21	Diversity; Transport, immunity, and gas exchange problems
February 28	Motivation; Digestive, endocrine and excretory systems problems
March 7	Learning Theory; Sensory systems problems
March 14	**SPRING BREAK**
March 21	Learning Theory; Animal Reproduction problems
March 28	Science Pedagogy; Genetic and DNA technology problems
April 4	Problem Solving Skills; Animal Development problems
April 11	Animal Behavior problems
April 18	Human Population and global environmental issues problems
April 25	Project presentations and PROJECT DUE
May 2	WRAP UP

Appendix E

The First Peer Led Team Learning Workshop Session Agenda

1. INTRODUCTION OF YOURSELF: Take a few moments to introduce yourselves to your students. Tell them what your major is, when you took BIO 123, what your future plans are such as pre-med, etc., and any other information that you may like to share with them related to academics.
2. STUDENT INTRODUCTIONS: Have your students introduce themselves to you and to each other. You can do this in any way that you would like. You may want to have them pair up and introduce themselves to each other, and then have them introduce their partner to the rest of the students. Or, you may have other icebreaker activities that you have done or would like to do with your students. Whatever you choose to do is fine, as long as you try to get the group to interact with each other a bit!
3. DESCRIPTION OF PLTL SESSIONS: Following introductions, you will want to describe how the Workshop sessions will run and what your role as a leader will be. Explain to the students that they will be working on problem sets as a group and that you are there to guide and help them through the material. Emphasize that you are not there to just give the answers, rather you will help them find good problem solving approaches to determine answers to the problems. Do this in a way that you are comfortable with!
4. EXPECTATIONS: You will need to be direct in explaining the expectations for the sessions. Tell the students that they are expected to be on time and actively participating in the problem sets to obtain the extra credit points. Also, emphasize that they are expected to be there for the full hour to receive credit. Students are also expected to print and bring the problem sets not completed with them to class. They will access the problem sets via blackboard.
5. PROBLEM SET: Have students begin to work on the problems together. As discussed in class, you can do the problems in whatever order you (and your students) decide, and you can break students up according to what will work best for the number of students you have.

Keep in mind that this is the first week of your session and that many students may not attend this week. They will likely be in the process of signing up for a time and so on. If no one has shown up for your session, please wait at least 15 minutes to see if any stragglers end up coming. If not, you are free to go. Have a great first week!

Appendix F

Problem Sets*

*Portions of Activity Instructions reproduced/modified from The Peer Led Team Learning Introductory Biology and Anatomy and Physiology Modules,
Progressions, V.7, No. 1, Fall 2005 – www.pltl.org info@pltl.org
Progressions, V.7, No. 3, Spring 2006 – www.pltl.org info@pltl.org

Photosynthesis and Respiration Problem Set

Activity 1. Scholarly Definitions

In groups of 2 or 3, evaluate the definitions below. Write TRUE if the entire definition is true. If it is not completely true, CIRCLE any part that is incorrect, and change the words to make it correct. Be prepared to share your work. As a large group, you will go over the definitions in round robin fashion.

1. Redox reaction: involves oxidation, or the gain of electrons, and reduction, the loss of electrons; occur as energy is transferred from one molecule to another; are involved in photosynthesis but not cellular respiration

2. Aerobic respiration: an anabolic process that requires oxygen; most cells use this process to obtain energy; glucose becomes oxidized while oxygen becomes reduced; transfers hydrogen directly from glucose to oxygen; includes glycolysis, formation of acetyl CoA, citric acid cycle, and electron transport and chemiosmosis, all of which take place in the mitochondria

3. Photosynthesis: uses light energy captured by chlorophyll to synthesize glucose; occurs in two reactions, the light-dependent reactions and the carbon fixation reactions; occurs in the thylakoid of the chloroplast

Activity 2. Short Problems

In groups of 2 or 3, solve the problem assigned to you by your peer leader. Be prepared to share your answer. A second problem will be assigned that has already been answered by another group; you may make corrections or additions to the answer or provide an alternative answer to the question.

1. Is cellular respiration an exergonic or endergonic reaction? Explain your answer.

2. Using the following, write the energy flow sequence in aerobic respiration: NADH, glucose, electron transport chain, ATP.

3. How does cellular respiration relate to photosynthesis?

4. What types of organisms go through the process of photosynthesis? Respiration?

Activity 3. Concept Map

In groups of 2 or 3, look over the list of terms and decide what the central concept is. Develop a concept map with the focus being to explain the central concept. Share your map with the rest of the group and others will add, correct, or improve the map with further details.

List 1: Glycolysis, Aerobic Respiration, Citric Acid Cycle, NADH and ATP, Electron transport chain and ATP synthesis, Acetyl CoA, Pyruvate

List 2: Photosystems I and II, Chemiosmosis, Light Dependent Reactions, G3P, Calvin Cycle, ATP and NADPH, Photosynthesis, RuBP, Glucose

Activity 4. Identifying Photosynthesis and Respiration Statements

Identify each statement below as photosynthesis (P) or respiration (R). Be prepared to give a short explanation for each answer.

_________ The final electron acceptor is oxygen.

_________ Involves chemiosmosis.

_________ Involves the enzyme Rubisco.

_________ Produces carbon dioxide, water, and energy.

_________ Is a redox reaction.

_________ Occurs in the thylakoids and stroma.

Plant Reproduction, Growth, and Development Problem Set

Activity 1. Flower Sketch

Pair up with a partner, and WITHOUT USING THE BOOK, draw a flower sketch with as many parts as you can. As you draw your sketch, discuss the functions of each part of the flower. When you have finished your sketch, give your drawing to another group. The next group will then add any missing parts to the sketch. You will then go around the room sharing your answers regarding the functions of all parts of the flower.

Activity 2. Review Questions

Students will go around the room to answer each of the questions below.

1. The female gametophytes develop in the ________________________, while the male gametophytes develop in the _________________________.
2. What type of evolution occurs when two species closely interact and become adapted to one another as they go through the process of evolution?
3. If a plant produces large quantities of pollen, it is likely pollinated via________________.
4. Fruit is a mature __________________.
5. Rhizomes, tubers, bulbs, corms, and stolons all involve which type of reproduction?
6. Growth in response to gravity is known as _________________________.
7. _____________________ promote cell elongation in stems and coleoptiles.
8. When you place fruit into a paper bag to cause it to ripen, you are stimulating what plant hormone?

Activity 3. Discussion Questions

In groups of 2 or 3, discuss the following questions. Be prepared to share your answers with the rest of the group.

1. What is the difference between self-pollination and cross pollination?

2. Discuss the various ways flowering plants attract pollinators.

3. Compare sexual and asexual reproduction in plants. Which is more advantageous and why?

4. List the four types of fruits and describe each type.

5. What is the difference between short day plants and long day plants? If the critical night length of a short day plant is 13 hours, would the plant be likely to flower if the plant was exposed to 16 hours of daylight and 8 hours of uninterrupted darkness?

6. Name and describe the role of two different plant hormones.

Activity 4. List of Words/Phrases
In small groups, decide what process each list below refers to, and then place the list of words/phrases in the correct order for the process.

1. Torpedo, globular, heart, fruit, embryo within seed, proembryo

2. Pollen tube becomes ovule, fertilization occurs, embryo develops in seed, pollen transferred by insect to stigma, insect drinks flower nectar

3. Zygote forms, two polar nuclei fuse with sperm cell, egg fuses with sperm, embryo develops

4. Conversion of Pr to Pfr, activation or repression of light-responsive genes, binding of Pfr to PIF3, red light absorption

Activity 5. Tropism Drawings
In groups of 2 or 3, make three different drawings to show the three types of tropisms: phototropism, gravitropism, and thigmotropism. Your group will present your drawings to the rest of the group.

Animal Structure Problem Set

Activity 1. Animal Tissues

In small groups, complete steps 1-4 by organizing your answers into a table(s). Use the information from your table(s) to complete 5. Each group will share its drawing with the rest of the group.

1. List the four main kinds of animal tissues.
2. For each **kind** you listed, name as many **types** of that tissue as you can.
3. For each **type** of tissue that you named, discuss its structure and function. (Ex. How many layers does it have, what is its general function, etc.?)
4. For each **type** of tissue that you named, make a diagram to represent it.
5. Using the diagrams you created for the various tissue types, draw a picture of the human body showing where the tissue types are found.

Activity 2. Organs

In your small group of 2 or 3, answer all the questions below. In a round robin fashion, students will share answers with the large group.

1. What is the relationship between tissues and organs?
2. Organs are not generally composed of one type of tissue. Why do you think this is?
3. Provide at least two examples of organs in the body that are composed of more than one type of tissue. For each example, discuss the types of tissue found in each organ and the role of that tissue in the organ.
4. When tissues and organs perform a specialized set of functions, what do they make up?

Activity 3. Discussion Questions

Your group will be assigned 2 or 3 of the questions below. Each group will then share their answers with the rest of the group. Students may offer further explanations, corrections, etc. as they listen to other groups' solutions.

1. Could a human body function without epithelial tissue? Explain your answer.
2. Cells of connective tissue are embedded in what type of substance? Using the blood as an example, explain the importance of this substance.
3. Why is it important that both cardiac and smooth muscle contractions are not controlled by our will?
4. Draw a typical neuron. Discuss how the specific structure of the neuron allows it to perform its function.
5. What allows organisms to function effectively, even under stress?
6. Why do you think most animals are ectotherms?
7. Besides the examples listed in your book, give an example of a positive and a negative feedback system.

Activity 4. Flow chart

A flow chart can be used to illustrate a sequence of steps in a process. For example, to complete PLTL Workshop activities:

Leaders split students into groups →Students work on problems →Groups explain their solutions to others in the larger group

1. **Using your own words**, briefly describe **negative feedback systems** using a flow chart.
2. **Using your own words,** briefly describe **positive feedback systems** using a flow chart.

Activity 5. Concept Map

In small groups, look over the list of terms, and develop a concept map connecting all the terms. Each group should share and compare their maps.

Ectotherm, Hibernation, Endotherm, Homeostasis, Thermoregulation, Surrounding Temperature, Metabolic Rate, and Acclimatization

Protection, Support, and Movement Problem Set

Activity 1. Concept Map of Skeletal Systems

Each student will receive a piece of paper or sticky note from their peer leader. On this paper, you should write down one (or more) word/phrase that you think of related to the topic of ***Skeletal Systems***. Your leader will then collect them and write them on the board. Together, as a large group, you will decide how to construct a concept map using all the words you have just listed. You can add in as many new words, connecting phrases, etc. as you many need to complete the map about the central concept: ***Skeletal Systems.***

Activity 2. Scholarly Definitions

In small groups, evaluate the definitions below. Write TRUE if the entire definition is true. If it is not completely true, CIRCLE any part that is incorrect, and change the words to make it correct. Be prepared to share your work with the rest of the group.

1. ***Muscle contraction***: muscles act antagonistically to one another, so a muscle can only be an agonist or an antagonist. The agonist contracts to produce a particular action, while the antagonist contracts to produce the opposite reaction.

2. ***Sequence of events in muscle contraction***: sensory neurons transmit messages to muscle fibers, acetylcholine is released causing depolarization of the sarcoplasm and generation of an electrical signal, a wave of depolarization travels to the T-tubules causing calcium to be released into the myofibrils, calcium binds to troponin and exposes actin filaments, actin-myosin complex then binds ATP, and Pi is released allowing the power stroke. As long as calcium is available, this sequence will continue from the first step.

3. ***Muscle fibers***: there are three types of muscle fibers, including slow-oxidative, fast oxidative, and fast glycolytic. Slow fibers are red due to a large amount of myoglobin, while fast fibers are white in color. Mitochondria are found more numerously in slow fibers because they are specialized for endurance activities and obtain their ATP from aerobic respiration, while fast fibers have fewer mitochondria because they use glycolysis to synthesize ATP.

Activity 3. Identifying Skeleton Type

Identify each statement below as hydrostatic (h), exoskeleton (ex), or endoskeleton (en).

____________The type of skeleton found in an earthworm
____________ Consists of plates or shafts of tissue containing calcium
____________ Are living
____________ Are jointed to allow flexibility
____________ Can include the axial and appendicular skeletons
____________ Found in many invertebrates
____________ Found on the top of the outer epithelium

____________ Fluid within compartments transmits force
____________ Can grow
____________ Can be composed of chitin
____________ Found in many mollusks and arthropods
____________ The type of skeleton you have

Activity 4. Short Problems

1. How are insect flight muscles able to contract more rapidly than any other muscles?
2. Compare and contrast the appendicular and the axial skeleton of the vertebrate.
3. What systems does the body depend on to effectively move? Of all the systems you named, which two systems function most closely together?
4. If ATP molecules can only provide energy for a few seconds of strenuous activity, than how can an endurance athlete, such as a marathoner or triathlete, continue to have enough energy for hours of activity?
5. Explain how summation and tetanus allows you to complete a task such as carrying a heavy book bag across campus.

Activity 5. List of Words/Phrases

For each of the words/phrases below, decide which one is the main concept that all others relate to or would fall under. Be prepared to explain why you think the word/phrase you chose is the main concept and how the others relate to it. Compare your answers with the rest of the groups.

1. Skin, Protection, Integumentary system, Epithelium, Gas exchange, Hair and nails, Cuticle
2. Compact, Marrow, Long, Spongy, Periosteum
3. Actin, Muscular System, ATP, Myosin, Mechanical Force
4. Sarcomeres, I band and H zone, Sliding Filament Model, Myosin and Actin, Shortened Length
5. Muscle fibers, Myofibrils, Sarcolemma, Skeletal Muscle, Sarcomere, A band

Internal Transport, Immunity, and Gas Exchange Problem Set

Activity 1. Identifying type of blood vessel

For each statement below, identify whether it describes **Arteries**, **Arterioles**, **Capillaries**, or **Veins.**

__________________________ Carry blood away from the heart
__________________________ Located close to every cell of the body
__________________________ Carry deoxygenated blood
__________________________ Return blood to the heart
__________________________ Walls are one cell thick
__________________________ Walls consist of three layers
__________________________ Help regulate blood pressure

Activity 2. Diagram of Human Heart

Pair up with a partner, and do a rough sketch of the human heart. Be sure to include as many chambers, valves, and major arteries/veins involved in blood circulation as you can. Do NOT label your diagram, but provide a list of words for another group to label the diagram. Upon completion of your sketch, your peer leader will assign you another groups' sketch to label. After labeling the diagram assigned to your group, refer to the textbook and draw in any missing parts of the heart.

After completion of all parts of the human heart diagram, number the steps of blood flow through the heart beginning with the superior vena cava and ending with the aorta.

Activity 3. Internal Transport Discussion Questions

1. What is the significance of the thickness of the capillary wall?
2. How is the pulmonary artery different than all other arteries of the body?
3. Why does blood flow in only one direction?
4. Compare the mammalian heart to the fish, amphibian, reptilian, and bird heart.
    a. How many atria does each heart have?
    b. How many ventricles does each heart have?
    c. Does blood flow through a single circuit or double circuit?
5. What is the advantage of having a circulatory system that separates oxygen-rich and oxygen-poor blood?

Activity 4. Sequential order

Place the following lists in the correct sequential order.

1. **Airflow**: nostril, bronchus, alveoli, bronchiole, pharynx, larynx, trachea
2. **Pulmonary circulation**: right ventricle, pulmonary vein, left atrium, right atrium, pulmonary artery
3. **Blood clotting**: fibrinogen, thrombin, prothrombin, fibrin

4. **Antibody-Mediated immunity:** B cell activated, pathogen is destroyed, B cell cloned, pathogen invades body, B cells differentiate into plasma cells, activated T cell interacts with B cell to display antigen, antibodies produced
5. **Cell-Mediated Immunity**: T cytotoxic cell activated by foreign antigen-MHC complex, T helper cells activated by foreign antigen-MHC complex presented by APC, T cytotoxic cells form clones and go to site of infection, activated T helper cell gives rise to a clone of T helper cells and memory cells, T cytotoxic cells destroy target cells, virus invades body
6. **Systemic circulation**: vena cava, right atrium, left atrium, aorta, arteries, capillaries, left ventricle, veins

Activity 5. Immunity Flowcharts

A flow chart can be used to illustrate a sequence of steps in a process. For example, to complete PLTL Workshop activities:

Leaders split students into groups →Students work on problems →Groups explain their solutions to others in the larger group

1. Using your own words, describe how HIV infects an individual. Begin with exposure to the virus.
2. Using your own words, describe the steps that may occur if an individual's body rejects transplanted tissue.

Activity 6. Short Problems on Immunity

1. Why is the Rh factor an important factor to worry about in a woman's second pregnancy, rather than her first?
2. Why is memory of the immune system important?
3. Two children are exposed to chicken pox, and one has been vaccinated while the other has not. How will their immune responses differ to the exposure?
4. Give an example of active immunity. Compare this to passive immunity.
5. Pregnant women are encouraged to breast feed their newborn babies. In terms of immunity, why is this important for the newborn's health?
6. How many classes of antibodies are there? Describe each class.
7. Which occurs first, nonspecific or specific immune response? How do the two types of immune responses work together to protect the body?

Activity 7. Gas Exchange Paragraph

Write down five sentences that come to mind when you think about gas exchange. Share your statements with 1 or 2 people near you. What did you have in common? What was different?

Activity 8. Gas Exchange Story

Using the list of words given below, in a small group of 2 or 3, write a story about the evolution of the respiratory system over time. You may include any additional words or concepts as you write your story. Be prepared to share your story with the larger group.

Adaptations	Inhalation
Respiratory surface	Exhalation
Tracheal tubes	Alveoli
Gills	Oxygen
Lungs	Diaphragm
Vertebrates	Surface area
Aquatic	Terrestrial

Digestive, Endocrine, and Excretory Systems Problem Set

Activity 1. Human Digestive System

As a group, you will construct a diagram of the human digestive system. One person should draw an outline of the human body on the board. Each student will then go to the board and draw and label one part of the digestive system. Continue to go around the room until everyone agrees all parts of the digestive system have been included in the diagram.

Upon completion of the diagram, in a round-robin fashion, students will discuss the functions of each part of the digestive system.

After discussing the functions of the digestive system, students will pair up and decide which part of the digestive system they feel is the most important and why. Each pair will then share their answer with the rest of the group.

Activity 2. Digestion of Carbohydrates, Proteins, and Lipids

Students will be divided into three groups. Each small group will be assigned one of the above by the peer leader. In your group, outline the steps of digestion as the nutrients travel through the digestive system. Be sure to include where digestion begins, the enzymes involved in the breakdown of the nutrient, as well as the end product of the breakdown. Be prepared to share your outline with the rest of the group.

Activity 3. Sequential Order-Excretory System

For each list, determine what process each list refers to, and then place the list in the correct order for the process.

1. Urethra, urinary bladder, kidney, ureter
2. Glomerular capillaries, efferent arterioles, renal vein, renal artery, afferent arterioles
3. Distal convoluted tubule, Bowman's capsule, collecting duct, proximal convoluted tubule, loop of Henle
4. Reabsorption, secretion, filtration
5. Aldosterone released, blood pressure decreases, blood pressure increases, renin secreted, production of angiotensin II

Activity 4. Discussion Questions

In small groups of 2 or 3, discuss the following questions. Be prepared to discuss your answers with the large group.

1. How does the endocrine system regulate the function of the kidney?
2. Are hormones involved in the digestive process? If yes, how so? Please provide examples.
3. What excretory structures evolved in invertebrates?
4. Using insulin and glucagon, explain how negative feedback regulates hormone action.
5. Discuss how the endocrine system works together with the nervous system to maintain homeostasis.

Activity 5. True/False

In small groups, determine whether each statement is true or false. For each false statement, explain why the statement is false and rewrite the statement to make it true. Share with the large group the statements you believe to be false and how you changed them to make them true.

1. Growth hormone is secreted in children only.
2. The two main types of cell-surface receptors that bind hormones are G-protein linked receptors and enzyme-linked receptors.
3. Hormones are not secreted in invertebrates.
4. The pituitary gland is responsible for controlling many other endocrine glands.
5. The thyroid gland secretes hormones related to diabetes.
6. If an individual is hypoglycemic, their thyroid level is too high.
7. Type 2 diabetes is due to genetics.

Activity 6. Endocrine diagram

Label the diagram on page 1050 of your textbook with the *hormones* that are secreted by each organ shown. After you have labeled the organs with the hormones they secrete, list the *target organ* (the organ that responds to it) for each hormone you have listed.

Neural Signaling & Regulation and Sensory Systems Problem Set

Activity 1. Polarization*

The inside of a neuron is typically -60 mV (resting membrane potential) which means that it is more negative than the extracellular fluid by 60 mV. This means the cell is polarized. When a ligand-gated Na^+ channel opens, Na^+ diffuses down its concentration gradient and enters the cell. Since Na^+ ions are positively charged, the inside of the cell becomes more positive. As the inside of the cell gains more positive charge, the membrane potential begins to move from the resting potential toward "0" (from –60 mV, to –59 mV, to –58 mV, etc.). This is called ***depolarization****. If the cell then opens a K^+ channel (which will allow K^+ to exit the cell) the positive charge inside the cell will begin to decrease (or move back toward the resting membrane potential). This is called* ***repolarization****, and only occurs as the membrane voltage returns to the resting membrane potential after a depolarization. If the K^+ channel stays open too long, the membrane potential will actually become more negative than –60 mV (it's like an overshoot). This is called* ***hyperpolarization****.*

Divide into groups. In the situations below, indicate whether the membrane potential is becoming more positive, or more negative. Then indicate whether the membrane is depolarized, polarized, repolarized, or hyperpolarized. Assume that the cell is starting off at the resting membrane potential for each scenario. Each group will complete two of the rows in the table below then share their answers with the group.

Na^+ enters the cell.
K^+ leaves the cell *after* Na^+ has entered the cell.
K^+ leaves the cell.

Activity 2. Graphing the potentials*

Use Round Robin to complete the following exercise on a graph on the board. Each person in the group should draw and label the portion of a graph that represents the actions described below.

1. The resting membrane potential in a neuron is –70 mV.
2. A molecule arrives at the dendrite and binds to its receptor on a ligand-gated Na^+ channel. Na^+ enters the cell and makes the membrane potential slightly more positive (-60 mV), but it does not trigger an action potential.
3. The positive membrane potential causes a voltage-gated K^+ channel to open and K^+ exits the cell. The cell then returns to its resting membrane potential.
4. This time, many molecules arrive at the neuron's dendrite and bind to its receptors on a ligand-gated Na^+ channels. Na^+ enters the cell and makes the membrane potential more positive (-55 mV), and this time the membrane potential is positive enough to trigger a voltage-gated Na^+ channel to open.

5. The voltage-gated Na^+ channel opens and makes the membrane potential more positive which causes another voltage-gated Na^+ channel to open and make the membrane potential more positive which causes another voltage-gated Na^+ channel to open and make the membrane potential more positive which causes another voltage-gated Na^+ channel to open and so on. There is therefore a sharp rise (happens quickly) in the membrane potential (up to +50 mV).

6. As the membrane potential is increasing, the Na^+ channels start to inactivate (kind of like they're getting worn out), and at the same time, voltage-gated K^+ channels become activated. K^+ exits the cell and the membrane potential repolarizes quickly.

Activity 3. Jeopardy*

The student that goes first will select a category and dollar amount. The peer leader will then read the question. The first person to raise their hand can try to answer the question. In Jeopardy, the "question" is actually a statement and the "answer" is to be phrased as a question. If a wrong answer is provided, another student will be given a chance to answer. Once a student has given the correct answer, "money" will be awarded and that student selects the next category and question.

Category 1. Anatomy of a neuron

$100: This is another name for the cell body
$200: The junction between a synaptic terminal and another neuron
$300: Conducts impulses away from the cell body to another neuron, muscle, or gland
$400: Receive stimuli and send signals to the cell body
$500: The insulating cover that axons of many neurons are surrounded by

Category 2. Action!

$100: The potential that a neuron must reach for an action potential to be generated
$200: The type of response an action potential is, because it occurs or it does not
$300: Closed channels at resting state
$400: The process in which the membrane potential returns to its resting state
$500: The level an axon depolarizes to in order to generate an action potential

Category 3: Signaling across synapses

$100: The two types of synapses
$200: A neurotransmitter that triggers muscle contraction
$300: The major excitatory neurotransmitter in the brain
$400: Causes synaptic vesicles to fuse with the plasma membrane and release neurotransmitter
$500: The type of neurotransmitter-receptor that hyperpolarizes the postsynaptic membrane

Activity 4. Withdrawal reflex*

1. What is a reflex?
2. Using your hand touching a hot burner on the stove as an example, explain the response carried out by neurons.

3. Determine if the following examples are reflexes or not. Be prepared to explain your answers to the group.
   a. A child removes their arm away from a friend in response to "cooties", or germs.
   b. Your heartbeat increases rapidly as you open your grades.
   c. You sit on a thumbtack and immediately jump up.
   d. You see your bus at the stop and you take off running.
   e. You hold your breath to swim across a pool.

*** Peer-Led Team Learning: Anatomy and Physiology, Module 8 –Nichole McDaniel-- Progressions, V.7, No. 3, Spring 2006 – www.pltl.org info@pltl.org**

<u>Activity 5. The Vertebrate Nervous System</u>

Using the list of words provided, construct a labeled diagram of the brain on the board in round robin fashion. Students may choose any word they would like to diagram. Feel free to add on to the diagram.

Parietal Lobe
Temporal Lobe
Occipital Lobe
Frontal Lobe
Cerebellum
Medulla
Spinal Cord
Thalamus
Hypothalamus
Pons
Midbrain

After finishing the diagram as a group, discuss the functions of each portion of the brain.

<u>Activity 6. Sensory Receptors Concept Map</u>

Look over the list of terms and develop a concept map with the focus being sensory receptors. Feel free to add in any other words/phrases that you would like.

Heat and cold
Touch
Pressure
Thermoreceptors
Light energy
Electroreceptors
Taste and smell
Nociceptors
Pacinian Corpuscles
Chemoreceptors
Photoreceptors
Gravity
Sharks, rays, and bony fish
Temperature
Pain
Mechanoreceptors

Animal Reproduction Problem Set

Activity 1. Applications of Mitosis and Meiosis in Gametogenesis*

Round robin done with a large version of the figures drawn on the board. Each student, in turn, will add items to the diagram. Other students may tactfully suggest modifications.

Gametogenesis is the development of gametes (eggs and sperm). In the testes of breeding males, one version of gametogenesis, called **spermatogenesis**, occurs producing millions of sperm each day in breeding males. Each meiotic sequence (two divisions) produces four tiny cells that will become spermatozoa. In the ovaries of females, meiosis occurs as well, but the timing and details are somewhat different. One important difference is that only one egg (**ovum**) is produced in each meiotic sequence. In this section of the workshop you will apply your knowledge of meiosis to the differing processes of **spermatogenesis** and **oogenesis**.

Spermatogenesis in Males

1. Figure 10.5 provides graphic outlines of cells in the stages of spermatogenesis. The cell at the top is shown in its prophase only. You will be adding the chromosomes to the other cells as directed in the following steps.

2. At the top of Fig. 10.5 is a stem cell located in the testis. Label it. Is it diploid or haploid? (Circle one).

3. Stem cells periodically undergo mitosis and of the daughter cells, one (**B**) becomes a primary spermatocyte, which will begin meiosis to form sperm, and the other (**C**) is a new stem cell. Add labels in Fig 10.5.

4. Distribute the chromosomes from the original stem cell into daughter cells **B** and **C** in Fig 2.5. Remember this is mitosis.

5. Before the primary spermatocyte can undergo meiotic division, it must go through the normal cell cycle including the S phase in which it replicates its single chromosomes, making them double chromosomes. In the cell outline marked **D** show the chromosomes of the cell after its S phase as it is entering Meiosis 1. Add one gene to each chromosome so that the cell is heterozygous for the two genes.

6. The first meiotic division occurs dividing cell **D** into two daughter cells **e** and **f**, called secondary spermatocytes. Show the chromosomes of these daughter cells with their alleles. Are the daughter cells genetically identical? _____ Haploid or diploid? _________

7. The second meiotic division occurs just as you've learned it, producing a total of four spermatids (**g, g', h, h'**). Show the genetic material and label the arrows. Explain the use of the labels with "primes". ____ .

8. Before the spermatids can function as gametes, they must undergo some important changes in a process called **differentiation**. The change converts the cells to a new functional form called **spermatozoa**.

9. Find and label the large **head** which contains the genetic material. Near the front of the head is an **acrosome** filled with enzymes to help the sperm chemically cut its way into the egg. Shown

to the right of the head is a **midpiece** filled with mitochondria, which produce the energy needed by the sperm as it moves through surrounding fluids toward the egg. Finally the **tail** is the elongated strand which whips rapidly back and forth propelling the sperm. Label the arrows indicating parts of the sperm in Fig 10.5.

10. Label Fig. 10.5. Following spermatogenesis where are the sperm stored and what is the eventual fate of them? ____

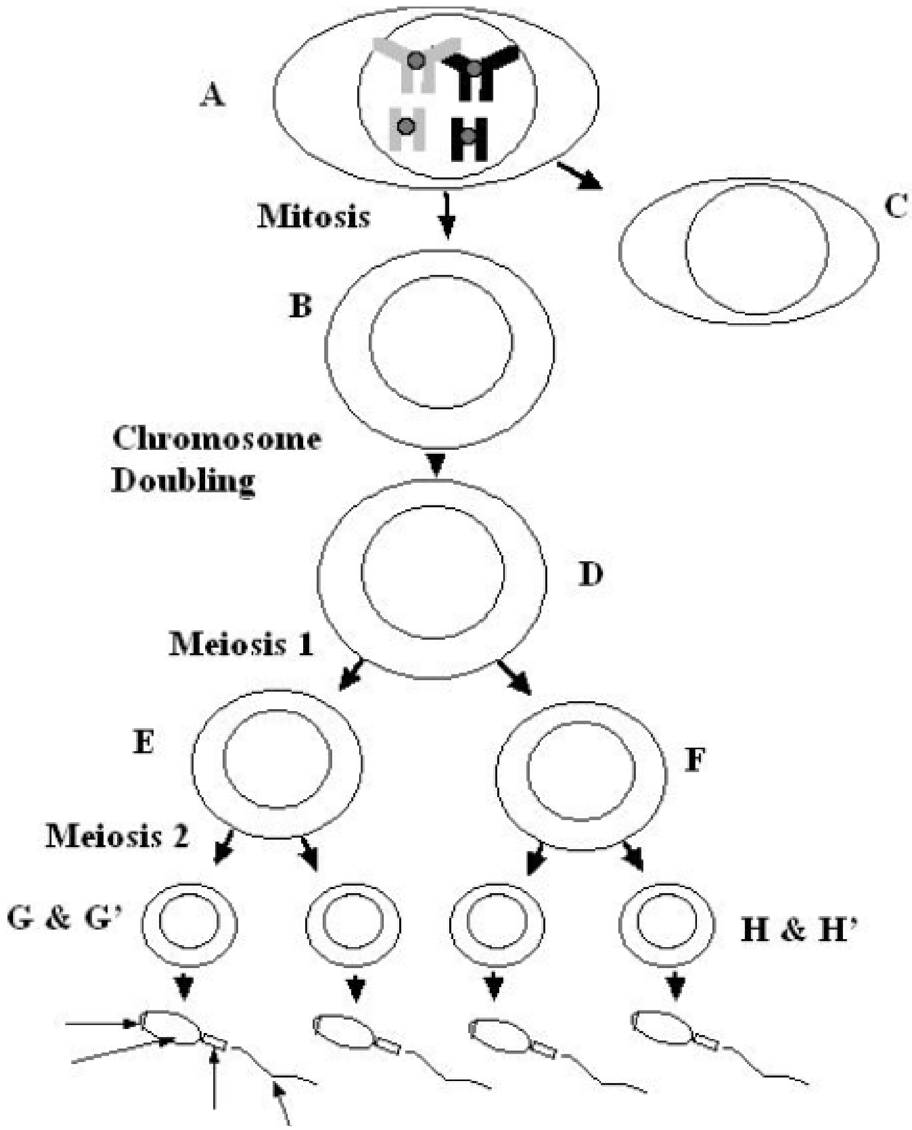


Figure 10.5. ____

Oogenesis in Females

1. Figure 10.6 provides graphic outlines of cells in the stages of oogenesis. The cell at the top is shown in its prophase only. You will be adding the chromosomes to the other cells as directed in the following steps.

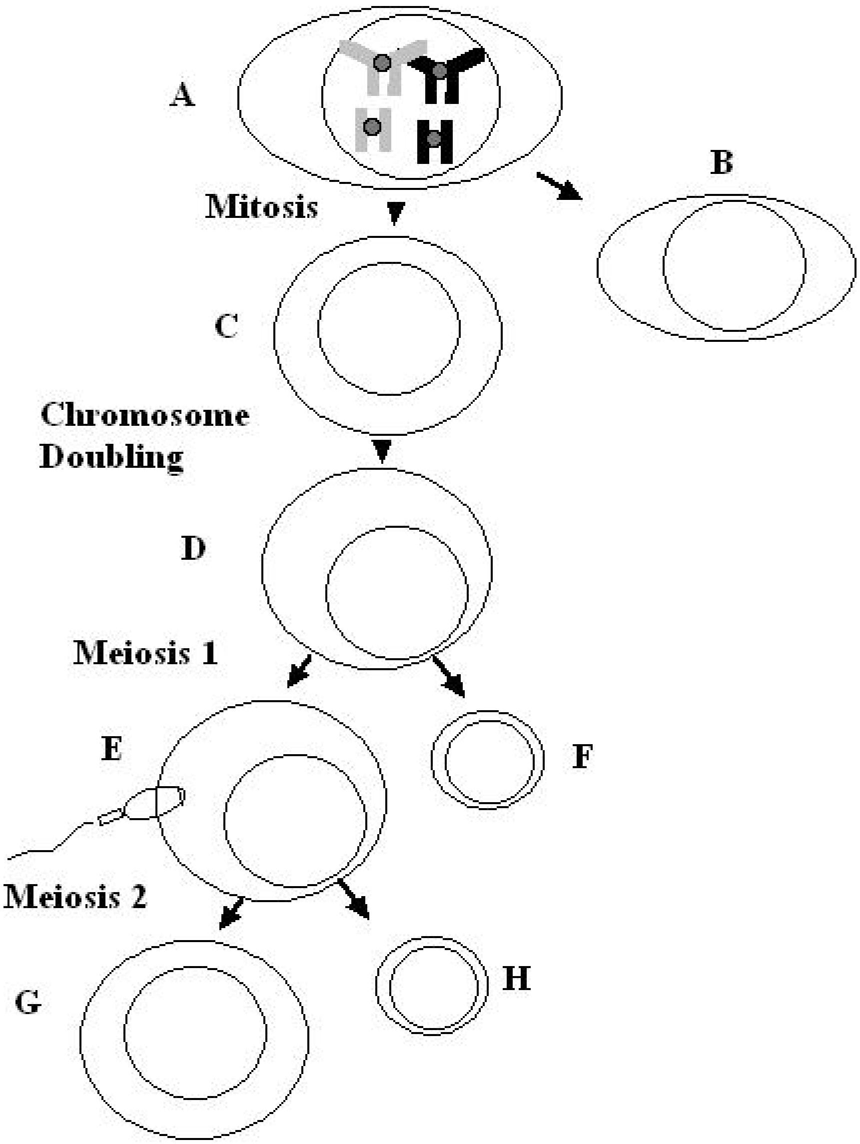


Figure 10.6. ____

2. At the top of Fig. 10.6 we show a stem cell dividing by mitosis to produce a primary oocyte (**C)** and another stem cell (**B**). Label them and fill in the genetic material so each chromosome has one gene and the cell is heterozygous for its genes.

3. Prior to meiosis, chromosome doubling occurs during the S phase of the cell cycle. Show the cell at **D** as it would appear in prophase of meiosis 1. Fill in the genetic material for this cell, including all the alleles.

4. Notice that as the first meiotic division is beginning, the nucleus of the cell is near the cell membrane, not in the center of the cell. The division is *unequal* because one cell gets most of the cytoplasm, while the other, called a **polar body**, gets only half of the genetic material. Add the genetic material to the unequal daughter cells of the first division. Label the first polar body. It will eventually degenerate and not participate in reproduction.

5. The remaining cell is a secondary oocyte. Is it haploid or diploid?__________________ This cell awaits the penetration of a sperm to undergo the second division. From Fig 10.6, how would you describe the second division in terms of the resulting daughter cells? __________________ The products are a **second polar body** and **ovum**. Label the cells after the second division and show the genetic material in each.

6. Suggest the reasons for unequal divisions in oogenesis? ________________________

7. Review and compare the production of eggs and sperm, and their final forms. What can these differences tell you about the different functions of the two types of gametes? Each student can add one item for the comparison. Comparing the structures and functions of sperm and ova.

*** Peer-Led Team Learning: Introductory Biology, Module 10, Page 12 – Joseph G. Griswold -- Progressions, V.7, No. 1, Fall 2005 – www.pltl.org info@pltl.org**

Activity 2. Concept Mapping

In small groups, look over the list of terms and decide what the central concept is. Develop a concept map with the focus being to explain the central concept; **you will need to add in your own words and phrases to make a complete map**. Share your map with the rest of the group and others will add, correct, or improve the map with further details.

List 1: Asexual, External fertilization, Reproduction, Hermaphroditism, Fragmentation, Parthenogenesis, Internal Fertilization, Sexual, Variation, Gametes, Budding, Zygote
List 2: Maturation, Epididymis, Ejaculatory duct, Storage, Vas deferens, Sperm, Urethra
List 3: FSH, Estrogen, Menstrual Cycle, LH, Preovulatory phase, Corpus Luteum, Negative Feedback

Activity 3. Birth Control Methods

1. List the main birth control methods.
2. For each method listed, discuss how the method prevents pregnancy.
3. Discuss the advantages and disadvantages of each method.
4. Why do you think most contraceptive methods were developed for females rather than males?
5. Can any of these methods prevent STD's? Explain.

Activity 4. Discussion Questions

1. Explain how negative feedback systems are involved in regulating male reproduction.
2. Explain how negative feedback systems are involved in the menstrual cycle.
3. Discuss the three stages of labor.
4. What is the difference between fertilization and conception?
5. What would happen if the corpus luteum did not form after ovulation?
6. How can a woman know that she is pregnant within days of missing her period?

Review Problem Set
(Endocrine and Excretory Systems; Neural Signaling and Regulation;
Sensory Systems; Animal Reproduction)

Activity 1. Jeopardy

The student that goes first will select a category and dollar amount. The peer leader will then read the question. The first person to raise their hand can try to answer the question. Remember to provide your answer in the form of a question.

Category 1. Endocrine System
$100: The concentration of this in the blood controls insulin and glucagon secretion
$200: Most endocrine action is regulated by this type of system
$300: Regulates the calcium level in the blood
$400: Stimulates reabsorption of water by the kidney
$500: The thyroid gland secretes these hormones

Category 2. Excretory System
$100: Consists of glomerulus, Bowman's capsule, and renal tubule
$200: When the body needs to conserve water, the posterior pituitary increases the release of this
$300: Nephridial organs found in flatworms
$400: Vary the salt concentration of their body fluids with changes in sea water
$500: The nitrogenous wastes

Category 3. Neural Signaling
$100: The process of detecting a stimulus
$200: Consists of hundreds or thousands of axons wrapped in connective tissue
$300: This type of synapse form gap junctions
$400: In this type of summation, repeated stimuli cause EPSPs to develop before previous EPSPs have decayed
$500: Includes norepinephrine, serotonin, and dopamine

Category 4. Neural Regulation
$100: An involuntary motor response to a stimulus
$200: A modified nerve net
$300: Functions in formation and retrieval of verbal and emotional memories
$400: The hormone released by the pineal gland that plays a role in regulating the sleep-wake cycle
$500: A signaling molecule in the memory pathway

Category 5. Sensory Systems
$100: Also known as afferent neurons
$200: Gravity receptors found in invertebrates
$300: Sensitive to deep pressure that causes rapid movement of the tissues
$400: The three bones of the middle ear

$500: Photopigments found in light sensitive receptor cells that cause chemical changes resulting in receptor potentials

Category 6. Animal Reproduction
$100: Budding is an example of this type of reproduction
$200: The type of fertilization is which gametes meet outside the body
$300: Responsible for primary and secondary male sex characteristics
$400: Most mammals have this type of reproductive cycle
$500: The hormone that maintains the corpus luteum

Activity 2. Scholarly Definitions

In small groups, evaluate the definitions below. Write TRUE if the entire definition is true. If it is not completely true, CIRCLE any part that is incorrect, and change the words to make it correct. Be prepared to share your work with the rest of the group.

1. **Birth Control Methods**: There are many contraceptive methods, including oral, injectable, intrauterine, and sterilization. All of these methods prevent pregnancy by inhibiting ovulation, but the most common method used in the world is oral contraceptives. The most reliable method, however, is sterilization of either the male or the female.
2. **Glucose Concentration**: The pancreas is an important endocrine gland that secretes both insulin and glucagon. Insulin and glucagon are secreted by clusters of cells, known as islets of Langerhans. Alpha cells secrete insulin, while beta cells secrete glucagon. Together insulin and glucagon maintain the appropriate blood glucose level. Insulin increases the concentration of glucose in the blood, while glucagon lowers the blood glucose level. If the blood glucose concentration is high, an individual will be diagnosed with type 1 diabetes.
3. **Metabolic Waste Products**: Metabolic wastes must be excreted before homeostasis is disrupted. There are three main metabolic wastes: water, carbon dioxide, and nitrogenous wastes. Nitrogenous wastes include ammonia and urine. Ammonia is usually converted to uric acid or urea before being removed from the body. Uric acid is the principal waste product of mammals, but urea is less toxic so it can be excreted in a more concentrated form. Urea is less soluble than uric acid, so it requires more water to excrete it.
4. **Sensory Receptors**: There are many types of sensory receptors including thermoreceptors, electroreceptors, nociceptors, mechanoreceptors, chemoreceptors, and photoreceptors. Thermoreceptors respond to heat and cold, while nociceptors respond to noise. Chemoreceptors respond to taste and smell, electroreceptors respond to electrical potential, and photoreceptors respond to darkness. Eyespots are an example of a photoreceptor, while sensilla are example of a mechanoreceptor.
5. **Peripheral Nervous System**: The PNS can be divided into the somatic and autonomic nervous systems. The somatic division can be further divided into the parasympathetic

and sympathetic systems. These two systems generally have opposite effects. For example, the sympathetic nervous system allows you to respond to the stress of taking a biology exam, while the parasympathetic nervous system will bring your heart rate back down when you have completed the exam. The somatic system responds to changes in the external environment, while the autonomic division responds to internal activities of the body.

6. **Conduction**: Continuous conduction is a smooth, progressive impulse transmission in unmyelinated neurons. The speed of transmission is proportional to the diameter of the axon, and the entire axon plasma membrane is involved. Saltatory conduction, on the other hand, is much more rapid than continuous conduction and occurs in myelinated neurons. Depolarization skips along the axon from one node of Ranvier to the next; ion activity at an active node results in diffusion of ions along the axon that depolarizes the next node. The distance between these nodes affects the speed of transmission.

Activity 3. List of Phrases

In small groups, decide what the main concept of each list is. Once you have determined what the main concept is, place the list of phrases in the correct order for the process.

1. Calcium channels open, Neurotransmitter binds with receptors, Synaptic Transmission, Synaptic vesicles fuse with plasma membrane, Depolarization, Action potential reaches synaptic terminal
2. Interneurons integrate information, Muscle contracts, Withdrawal Reflex, Sensory neuron receives stimulus, Motor neuron transmits signal, Sensory neuron transmits signal
3. Oval window vibrates, Tympanic membrane vibrates, Basilar membrane vibrates, Hearing, Hair cells rub against tectorial membrane, Cochlear nerve transmits impulses to the brain, Ear bones transmit and amplify vibrations, Sound waves enter auditory canal, Fluid of vestibular canal vibrates, Round window bulges
4. Thyroid hormone concentration is high, Thyroid hormone concentration low, Anterior pituitary inhibited, Anterior pituitary secretes TSH, Homeostasis, Negative feedback of thyroid secretion, Thyroid gland secretes more hormone, Thyroid secretes less hormone
5. FSH and LH secreted, Sertoli cells stimulated, GnRH secreted, Male reproduction, Spermatogenesis, Testosterone inhibits FSH and LH, Testosterone maintains secondary sex characteristics, ABP and signaling molecules secreted, Testosterone secreted, Anterior Pituitary stimulated, Testosterone inhibits GnRH, Inhibin inhibits secretion of FSH

Activity 4. Concept Map

Look over the list of terms and develop a concept map with the focus being “Human Vision”.

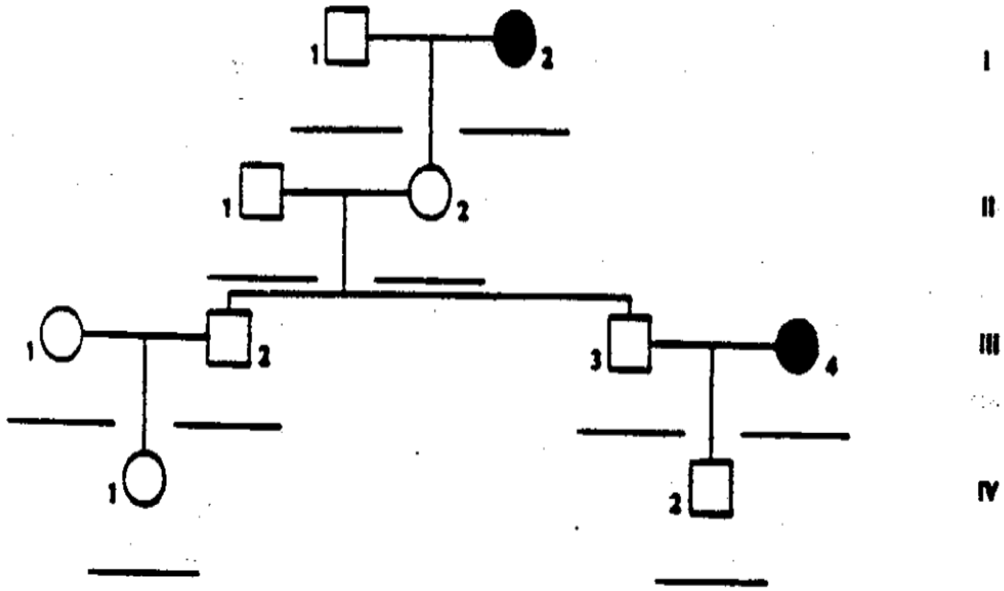
Retina	Rhodopsin
Rods	Bipolar cells
Cones	Ganglion cells

Photoreceptors	Transducin
Optic Nerve	Cerebral cortex
Horizontal cells	Amacrine cells
Cornea	Aqueous fluid
Thalamus	

Genetic and DNA Technology Problem Set

Activity 1. Pedigree Analysis*

A. Examine the following pedigree representing albinism in a family:



1. How many generations are shown?
2. How many people are albinos?
3. How many people are not albinos?
4. Identify by generation and number those people with albinism.
5. What is the genotype of all people with albinism?
6. How many children are in the original generation?
7. Predict the genotypes for all people in the pedigree using the lines below each person's symbol.

***Source Unknown**

B. With a partner, create a pedigree illustrating the inheritance pattern of PKU in a family. Two normal individuals marry and have three children, two of which have PKU. One of the mother's parents has PKU, while the other is a carrier of the gene. The mother's parents had four children including her. The father's parents are both carriers of the PKU gene, but neither has the disorder. They had three children including him.

After completing your pedigree, be prepared to share it with the rest of the group.

After all groups have shared their pedigree, answer the following questions:

1. What do you notice about the pedigrees? Are they all exactly the same? Why or why not?
2. How can a pedigree be useful to a genetic counselor?
3. What three types of genetic inheritance to pedigrees most often identify?

Activity 2. Identifying Inheritance Pattern

1. Determine what it means to inherit a disorder through a chromosomal abnormality, autosomal dominant pattern, autosomal recessive pattern, or sex-linked pattern.
2. Identify the inheritance pattern of the following diseases as: chromosomal abnormality, autosomal dominant, autosomal recessive, sex-linked, or unknown.

Down Syndrome____
PKU____
Sickle Cell Anemia____
Klinefelter's____
Albinism____
Patau Syndrome____
Huntington's Disease____
Fragile X Syndrome____
Cri du chat Syndrome____

Activity 3. Flow Charts of Prenatal Diagnosis

A flow chart can be used to illustrate a sequence of steps in a process. For example, to complete PLTL workshop activities:

Leaders split students into groups→Students work on problems→Groups explain their solutions to others in the larger group

1. Using your own words, describe the process of amniocentesis.
2. Using your own words, describe the process of chorionic villus sampling.

After sharing your flow charts with the large group, answer the following questions:

1. For what reasons would a woman have these techniques performed?
2. During what part of the pregnancy can these techniques be performed?
3. What reasons can you think of for a woman having amniocentesis done rather than chorionic villus sampling?

<u>Activity 4. Genetic Discrimination*</u>

As a group, discuss what genetic discrimination means. Your peer leader will then read you "The Case of Nathaniel Wu". After hearing the story, discuss the following in small groups:

1. Come up with as many reasons as you can for why IPC may or may not hire Nathaniel Wu. Your peer leader will write each reason on the board.
2. For each reason, discuss as a group: is that fair? Is that legal?
3. Do you agree that employers or insurers should have access to this type of genetic information?

***1992 by BSCS & The American Medical Association.**

Animal Development Problem Set

Activity 1. Germ Layers
In small groups, answer the following questions.

1. During which process do the germ layers of the body form?
2. What do germ layers refer to?
3. How many germ layers are there? Name them.
4. Decide what germ layer(s) each of the examples below developed from:

Brain	Reproductive System	Circulatory System
Fingernails	Hair	Eyes
Digestive System	Skin	Muscles
Spinal Cord	Cartilage	Liver
Lungs	Excretory System	Skeleton
Amnion	Chorion	Allantois

Your peer leader will write all the germ layers on the board. In a round robin fashion, each group will share their answer to one of the examples above until all examples have been categorized. After each answer, students in other groups may offer corrections, additional explanations, etc.

Activity 2. Sequential Order
In small groups, determine what process each list refers to and place the following in the correct sequential order. Be prepared to share and explain your answers to the rest of the group.

1. Regulation of sperm entry, DNA synthesis, Activation of the egg, Contact and Recognition, Formation of Diploid Nucleus
2. Cleavage, Blastocyst Develops, Fertilization, Implantation, Chorion and Amnion Form
3. Early Cleavage, Morula, Gastrula, Zygote, Blastula

Activity 3. Scholarly Definitions
In small groups, evaluate the definitions below. Write TRUE if the entire definition is true. If it is not completely true, CIRCLE any part that is incorrect, and change the words to make it correct. Be prepared to share your work with the rest of the group.

1. **Fertilization**: After contact and recognition, fertilization of the egg by more than one sperm, known as polyspermy, is prevented through one of two reactions. These reactions are the fast block and slow block. The fast block is a complete block, while the slow block involves depolarization of the egg plasma membrane. Once the cortical reaction, or fast block, occurs, the activation program of the egg is triggered. The activation includes increased aerobic respiration, activation of proteins, and DNA synthesis. The

last event of fertilization involves a haploid male and haploid female pronucleus fusing to form a diploid nucleus. Protein synthesis then occurs to prepare for cell division.

2. **Cleavage**: The pattern of cleavage is affected by yolk. Most vertebrates have isolecithal eggs with small amounts of yolk uniformly distributed through the cytoplasm. These eggs divide completely, known as holoblastic cleavage. Holoblastic cleavage is radial or spiral. Radial cleavage splits the egg into two equal cells by a horizontal division. The second division is vertical, and separates the egg into four equal cells. The third division is also vertical and separates the cell into eight cells. Radial cleavage is very common in protostomes. Spiral cleavage, on the other hand, is very common in echinoderms and results in a spiral arrangement of cells. Telolecithal eggs have large amounts of yolk concentrated at one end of the cell, and invertebrates exhibit meroblastic cleavage.
3. **Human Development**: The placenta is the organ of exchange between mother and embryo. The placenta provides both nutrients and oxygen for the fetus, as well as removing wastes from the fetus. The placenta develops from the amnion of the embryo and the uterus of the mother. As the embryo grows, the umbilical cord develops and connects the embryo to the placenta. The umbilical cord contains two umbilical veins and one umbilical artery. While the blood of the fetus and mother come in close contact, maternal and fetal blood do not normally mix unless in the placenta. The placenta produces several hormones.

Activity 4. Short Problems

1. Discuss the changes that occur in a neonate to allow them to live independently after birth.
2. If maternal and fetal bloods do not directly mix, explain how teratogenic medications and other environmental influences can affect life before birth.
3. Compare gastrulation in birds and amphibians.
4. What is the acrosome reaction, and what is the purpose of the reaction?
5. What is the difference between fraternal and identical twins?

Activity 5. Cleavage Diagrams

As a group, draw a series of diagrams to illustrate:

1. Divisions in radial cleavage and gastrulation
2. Divisions in spiral cleavage and gastrulation
3. The difference between divisions in an isolecithal egg and a telolecithal egg
4. The difference between holoblastic and meroblastic cleavage

Animal Behavior Problem Set

Activity 1. Concept Map

In groups of 2 or 3, look over the list of terms and decide what the central concept is. Develop a concept map with the focus being to explain the central concept. You can add in as many additional words/phrases as necessary. Share your map with the rest of the group, and others will add, correct, or improve the map with further details.

List 1: Ignore, Imprinting, Pavlov, Positive Reinforcement, Learning, Avoid Punishment, Cognition, Warning Coloration, Reflex, Play
List 2: Evolutionary explanations, Environmental Factors, Adaptive, Behavior, Innate, Coordinated Muscle Actions, Physiological Readiness, Reproductive Success

Activity 2. Discussion Questions

1. Explain the difference between intrasexual and intersexual selection. Be sure to provide examples in your explanation.
2. In your own words, define altruism. Based on the definition, why would individuals engage in this type of behavior?
3. Animals communicate in various ways. Why do you think animals would use visual signals? What type of communication would be used in the dark and why? Explain how pheromones are a means of communication.
4. Which mating system is very uncommon and why?
5. What is the difference between classical and operant conditioning? (You will need to come up with a definition of these terms prior to completing Activity 3.)

Activity 3. Identification of Type of Conditioning

Identify the following as examples of classical or operant conditioning. Be prepared to explain why you identified your answer as such.

1. An animal learning to forage efficiently.__________________
2. A dog runs into the room when it hears a bag of chips crinkle.________________________
3. A toddler who is potty training receives a piece of candy each time she tries to go to the bathroom. She begins to go to the bathroom more and more._________________________________
4. A student in class is praised for answering correctly. As a result, the student begins to answer more questions. ________________________________
5. Your car makes an obnoxious beeping sound when you leave the keys in the ignition when the door is open, so you stop leaving the keys in the ignition when your car door is open._________________________
6. A child had a snake put around her neck while her eyes were closed, and now she is afraid every time she sees a snake.___________________________

7. A runner broke her ankle on black ice. She now runs around any shiny or wet looking pavement when running in the winter.____
8. A pregnant woman drinks coffee and becomes nauseous. Now, every time she smells coffee, she feels nauseated. _____________________________
9. A dog has an invisible fence. When trying to run out of the yard, the dog gets a shock. After a few times, the dog stops running past a certain point in the yard. ________________________
10. The dog immediately runs to the door in excitement when he hears a leash rattle. ______________________

Based on how you answered the above, please answer the following questions:

a. How did you determine whether or not something was classical or operant conditioning? What criteria did you use?
b. Can you think of an example that includes both classical and operant conditioning? Share your example with the rest of the group.

Activity 4. Jeopardy

The student that goes first will select a category and dollar amount. The peer leader will then read the question. The first person to raise their hand can try to answer the question. Remember to provide your answer in the form of a question.

Category 1. Learning

$100: Learning involves changes in this that result from experience
$200: A type of learning in which an animal learns to ignore an irrelevant stimulus
$300: This type of learning occurs during a critical period, usually right after birth
$400: Includes thinking, processing information, learning, reasoning, perception, etc.
$500: Another name for warning coloration

Category 2. Biological Rhythms

$100: Daily cycles of activity
$200: Animals that are most active during the day
$300: The biological cycle that reflects the phases of the moon
$400: Animals that are most active at dawn or dusk
$500: In mammals, the master clock is located in this within the hypothalamus

Category 3. Behavior

$100: The type of behavior that is inborn
$200: The type of behavior that has been modified in response to environmental experiences
$300: This type of cause includes immediate causes such as genetic and developmental processes
$400: A type of cooperative behavior in which an individual seems to benefit others rather than itself
$500: The two body systems that behavior is mainly influenced by

Category 4. Sexual Selection

$100: Mating with a single partner during a breeding season
$200: These type of rituals allow females to determine if a male is indeed a male
$300: A mating system in which males fertilize the eggs of many females during a breeding season
$400: The mating system in which one female mates with many males
$500: A small display area where males gather to compete for females

Appendix G

Reminder Email to Control Group Participants

It's spring and time for those who participated in January in Julia Snyder's research on critical thinking skills to come back and take the post-test and open-ended questionnaire. Remember, the time you put into taking the pre-test is wasted unless you take a bit more time to also take the post-test. To make this easy for you, here are the important points:

- All post-test takers will have their name put into a drawing for a $100 gift card at the SU bookstore (You will have a 1 in 75 or greater chance of winning the gift card!)
- The post-test takes a <u>maximum</u> of 45 minutes, but it should take a similar amount of time as the pre-test
- You can make an appointment to take the post-test with Bev Werner at a time that suits your schedule during the week of April 25 – 29
- Please email Bev at bfwerner@syr.edu to arrange to take the post-test; times available are Monday, April 25 – Friday, April 29, 9 am – 4 pm.
- Please come and take the post-test so we get 100% of the original pre-test takers! Hooray!

Bev Werner
Course Coordinator Biology 121/123
142 Life Sciences Complex
Syracuse University
315-443-3722
bfwerner@syr.edu

Appendix H

Pizza Party Email to Control Group Participants

It's the end of the semester and a very busy and stressful time for you. So, how about free pizza?

To thank you for your participation in Julia Snyder's research on critical thinking, we would like to offer you a **FREE PIZZA LUNCH** during the **reading day on Wednesday, May 4**. If you would like to join us for pizza:

* Please let Bev know ASAP at bfwerner@syr.edu

* Tickets will be available for pick up on Wednesday, May 4. The number of tickets issued will determine the number of pizzas we order, so to make sure there’s plenty of pizza, pick up your ticket from Bev at 11:00 am!

* For ticket holders, pizza will be served at 12 noon (Location to be announced)

* If you have not taken the post-test yet, you can still take the post-test during the hour between picking up your ticket and pizza time (Remember, the post-test takes a maximum of 45 minutes, and all post-test takers will be entered into a drawing for a $100 gift card at the SU Bookstore).

Appendix I

Oral Consent Script

Thank you for coming to take the CCTST post-test and open-ended questionnaire for Julia Snyder's research study on critical thinking skills. Participation in the post-test of critical thinking skills and the open-ended questionnaire is voluntary. If you begin the post-test and no longer wish to continue, you can withdraw from the study at any time, without penalty. You will still be entered into the drawing to win a $100 gift card (with a 1 in 75 or greater chance to win the gift card) to the Syracuse University Bookstore should you choose to withdraw from the study after beginning the post-test of critical thinking skills.

Appendix J

Revised Oral Consent Script (Control Group)

Thank you for coming to take the CCTST post-test and open-ended questionnaire for Julia Snyder's research study on critical thinking skills. Participation in the post-test of critical thinking skills and the open-ended questionnaire is voluntary. If you begin the post-test and no longer wish to continue, you can withdraw from the study at any time, without penalty. You will still be able to attend the free pizza lunch and be entered into the drawing to win a $100 gift card (with a 1 in 75 or greater chance to win the gift card) to the Syracuse University Bookstore should you choose to withdraw from the study after beginning the post-test of critical thinking skills.

Appendix K

Critical Thinking Questionnaire

1. How do you think you did on the critical thinking pre-test (at the beginning of the semester)? Compared to the critical thinking post-test?

2. How have your critical thinking skills changed since the beginning of the semester?

3. What do you think contributed to your change in critical thinking skills?

4. If you participated as a PLTL leader, how did your experience as a workshop leader influence your critical thinking skills?

Appendix L

Email to Control Group Participants (Online Instructions)

Hello,

My name is Julia Snyder. At the beginning of the semester, you took a pre-test of critical thinking skills for my research project. Because you did not get into the Biology 200 class on PLTL, you became part of the control group. As former biology students, you know the importance of a controlled study. Without your post-test, I cannot incorporate any of your pre-test data into my research.

To make the post-test as easy as possible for you to take, the test will be available for you to take online. You were all assigned a confidential number that only a third party has had access to up to this point, however, I will now use those confidential numbers along with a unique login and password to make the test accessible online. All data obtained from this study will be kept only until the research project has been defended. If you could please take the time to complete the post-test, I would greatly appreciate it.

- You can take the post-test online anywhere and anytime that is convenient for you beginning May 12, 2011 by clicking the "**Test Taker Login**" button at www.insightassessment.com. I will notify each of you individually with your login information.
- All post-test takers will have their name put into a drawing for a $100 gift card at the SU bookstore (You will have a 1 in 75 or greater chance of winning the gift card!)
- The post-test takes about 45 minutes, but it should take a similar amount of time as the pre-test

Participation in the post-test of critical thinking skills is voluntary. If you begin the post-test and no longer wish to continue, you can withdraw from the study at any time, without penalty. You will still be entered into the drawing to win a $100 gift card (with a 1 in 75 or greater chance to win the gift card) to the Syracuse University Bookstore should you choose to withdraw from the study after beginning the post-test of critical thinking skills.

Thank you,

Julia Snyder

Table 1

Demographics for PLTL and Non-PLTL Groups (Class standing & Gender)

		Class Standing (%)				Gender (%)	
	n	Fr	So	Jr	Sr	M	F
PLTL	37	0	38	51	11	43	57
Non-PLTL	17	0	75	19	6	41	59
Total	**54**	**0**	**56.5**	**35**	**8.5**	**42**	**58**

Table 2

Demographics profile for PLTL and Non-PLTL Groups (Ethnicity)

Method	**n**	**Ethnicity (%)**				
		White	Black	Hispanic/Latino	Asian	Other
PLTL	37	76	5	8	8	3
Non-PLTL	17	47	18	18	12	6
Total	**54**	**61.5**	**11.5**	**13**	**10**	**4.5**

Note. Racial categories used by the university in this study.

Table 3

Major and Number of Science Courses taken Prior to Spring 2011 for PLTL and Non-PLTL Groups

Method	**n**	**Major (%)**		**Number of Science Courses Prior to Spring 2011 Term (%)**					
		Science	Non-Science	2	3	4	5	6	6+
PLTL	37	84	16	3	5	5	0	14	73
Non-PLTL	17	76	24	18	0	12	18	6	47
Total	**54**	**80**	**20**	**10.5**	**2.5**	**8.5**	**9**	**10**	**60**

Table 4

Number of Science Courses taken During Spring 2011 for PLTL and Non-PLTL Groups

		Number of Science Courses During the Spring 2011 Term (%)							
Method	**n**	0	1	2	3	4	5	6	6+
PLTL	37	0	19	32	27	16	0	3	3
Non-PLTL	17	6	12	24	24	24	0	6	6
Total	**54**	**3**	**15.5**	**28**	**25.5**	**20**	**0**	**4.5**	**4.5**

Table 5

Recommended CCTST Categorical Cut Scores

	High Cut	**Low Cut**
Total Score	>24	<12
Analysis and Interpretation	>4	<3
Inference	>11	<6
Evaluation and Explanation	>9	<4
Inductive Reasoning	>11	<6
Deductive Reasoning	>11	<6

Table 6

Overall Critical Thinking Raw Score Gains by Group

Method	**n**	**Mean (pre)**	**SD (pre)**	**Mean (post)**	**SD (post)**	**CT Change**
PLTL	37	18.46	3.48	18.76	4.18	0.30
Non-PLTL	17	17.82	3.86	16.35	6.36	-1.47
Total	**54**	**18.14**	**3.67**	**17.56**	**5.27**	**-0.59**

Table 7

Influence of Method on Critical Thinking Sub-Scale Scores (Inductive Reasoning, Deductive Reasoning, Analysis & Interpretation)

Method	n	Critical Thinking Sub-Scale Scores					
		Inductive Reasoning (pre)	Inductive Reasoning (post)	Deductive Reasoning (pre)	Deductive Reasoning (post)	Analysis & Interpretation (pre)	Analysis & Interpretation (post)
PLTL	37	10.03 (1.99)	9.89 (2.07)	8.43 (2.35)	8.86 (2.89)	4.05 (1.15)	3.84 (1.34)
Non-PLTL	17	8.29 (1.76)	8.82 (3.58)	9.53 (3.00)	7.53 (3.11)	4.41 (1.50)	3.65 (1.46)
Total	**54**	**9.48 (2.07)**	**9.56 (2.65)**	**8.78 (2.60)**	**8.44 (3.00)**	**4.17 (1.27)**	**3.78 (1.37)**

Note. Standard deviations are in parentheses.

Table 8

Influence of Method on Critical Thinking Sub-Scale Scores (Inference, Evaluation & Explanation)

		Critical Thinking Sub-Scale Scores			
Method	**n**	Inference (pre)	Inference (post)	Evaluation & Explanation (pre)	Evaluation & Explanation (post)
PLTL	37	9.62(2.30)	9.86(2.15)	4.78(1.38)	5.05(1.81)
Non-PLTL	17	9.71(2.20)	8.71(3.08)	3.71(1.83)	4.00(2.42)
Total	**54**	**9.65(2.25)**	**9.50(2.51)**	**4.44(1.60)**	**4.72(2.06)**

Note. Standard deviations are in parentheses.

Table 9

Peer Leader Perception of Critical Thinking Skills

Peer Leader CT Skills	Actual (%)	Perception (%)
Improvement in CT Skills	43	62
No Improvement in CT Skills	57	38

Table 10

Mean Scores of Biology 123 Students

Group	**n**	**Mean Final Exam Score**	**Mean Final Course Grade**
PLTL	136	79.38 (0.10)*	80.15(8.64)*
Non-PLTL	247	74.89 (0.19)*	75.75(16.08)*
Total	**383**	**77.14 (0.15)**	**77.95(12.36)**

Note. Standard deviations are in parentheses.
* Significant at $p < .05$ for the means, PLTL vs. Non-PLTL.

Table 11

Percentage of Final Course Grades of Biology 123 Students

Grade Percentage	**PLTL (n=136)**	**Non-PLTL (n=247)**
%A	14.0	12.6
%B	42.6	34.8
%C	36.0	34.4
%D	6.6	10.1
%F	0.7	8.1
%ABC	**92.6***	**81.8***
%DF	**7.3***	**18.2***

Note. Grade percentage was calculated by summing all students with each grade and dividing by the total number of students enrolled in each group.
*Significant at $p < .05$, PLTL vs. Non-PLTL.

Table 12

Final Course Grade Performance of Biology 123 Students by Group

Group	n	Mean	Standard Deviation	Standard Error of the Mean
Non-PLTL and Non-Lab	78	67.63*	21.45	2.43
PLTL and Non-Lab	26	78.09	8.63	1.69
Non-PLTL and Lab	169	79.50	11.10	0.85
PLTL and Lab	110	80.64	8.61	0.82
Total	**383**	**77.32**	**14.05**	**0.72**

*Non-PLTL and Non-Lab mean significantly lower than PLTL and Non-Lab, Non-PLTL and Lab, and PLTL and Lab at $p < .05$. No significant differences between PLTL and Non-Lab, Non-PLTL and Lab, and PLTL and Lab.

Figure 1.

Quasi-Experimental Design

Treatment Group

O____________________X____________________O

Control Group

O____O

Figure 1. Quasi-Experimental Design. Treatment and control groups take a pre-test and post-test (O). Only the treatment group receives the treatment (X).

Figure 2.

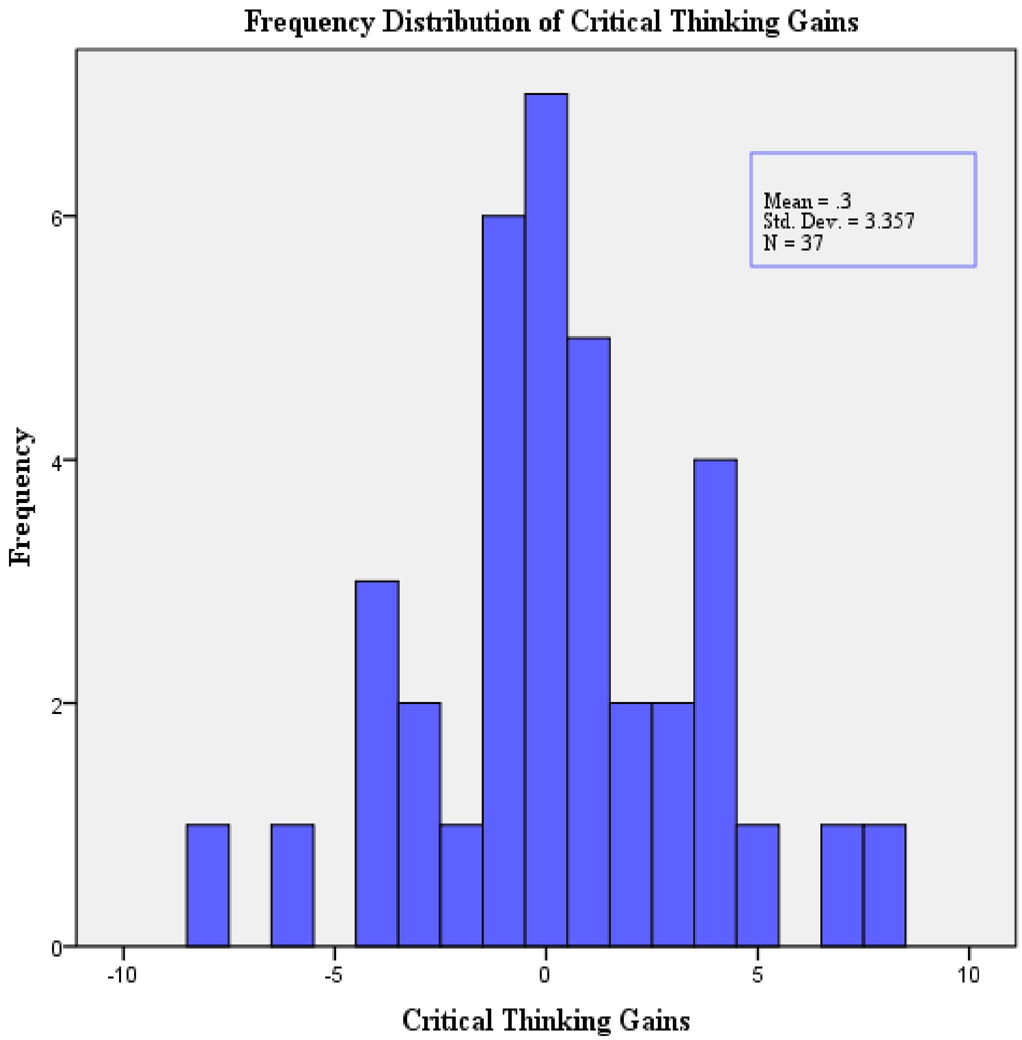


Figure 2. Distribution of critical thinking gains for the treatment group. Gains are indicated by the difference in CCTST pre-test and post-test scores.

Figure 3.

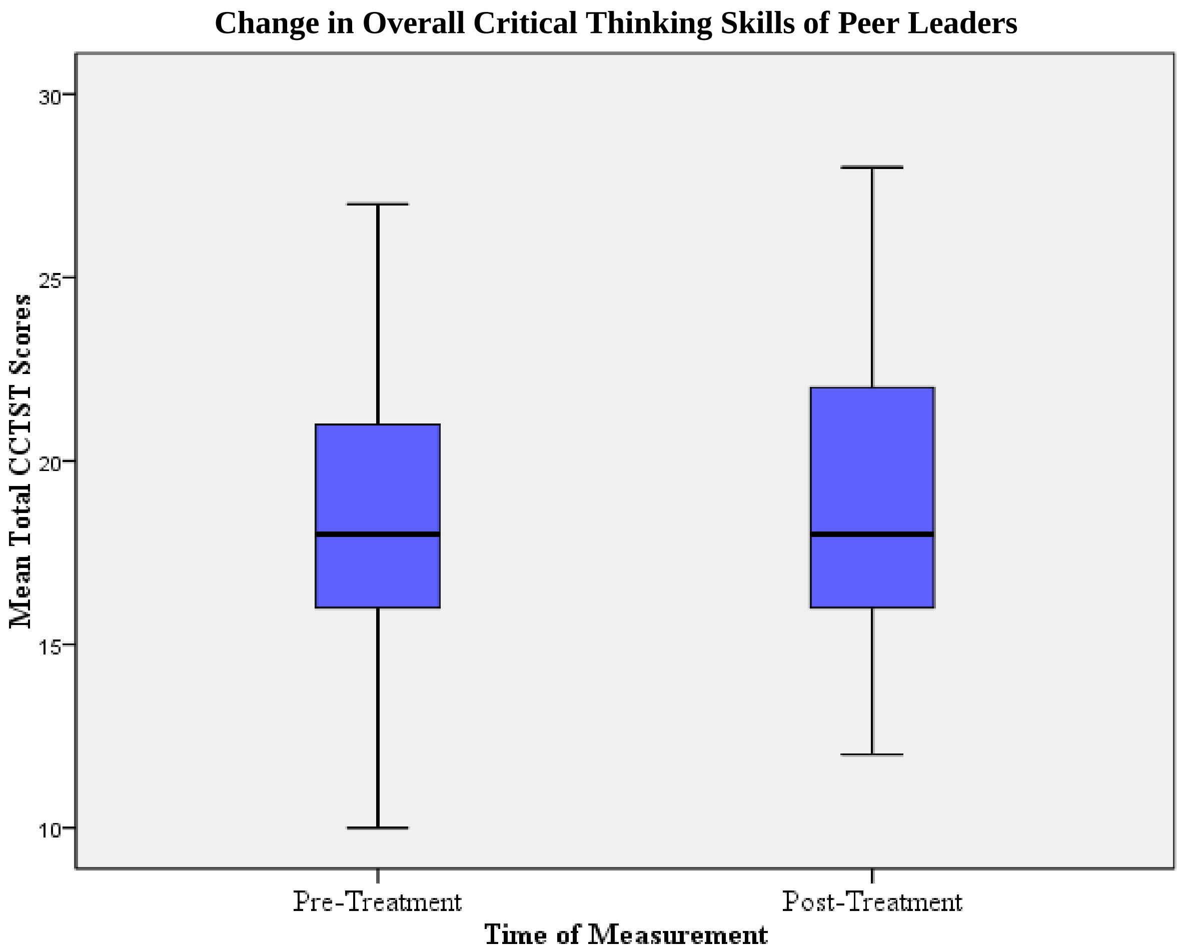


Figure 3. Mean total CCTST scores of peer leaders before and after the peer-led team learning training and leadership experience. Error bars indicate 1 standard deviation from the mean. n= 37 peer leaders.

Figure 4.

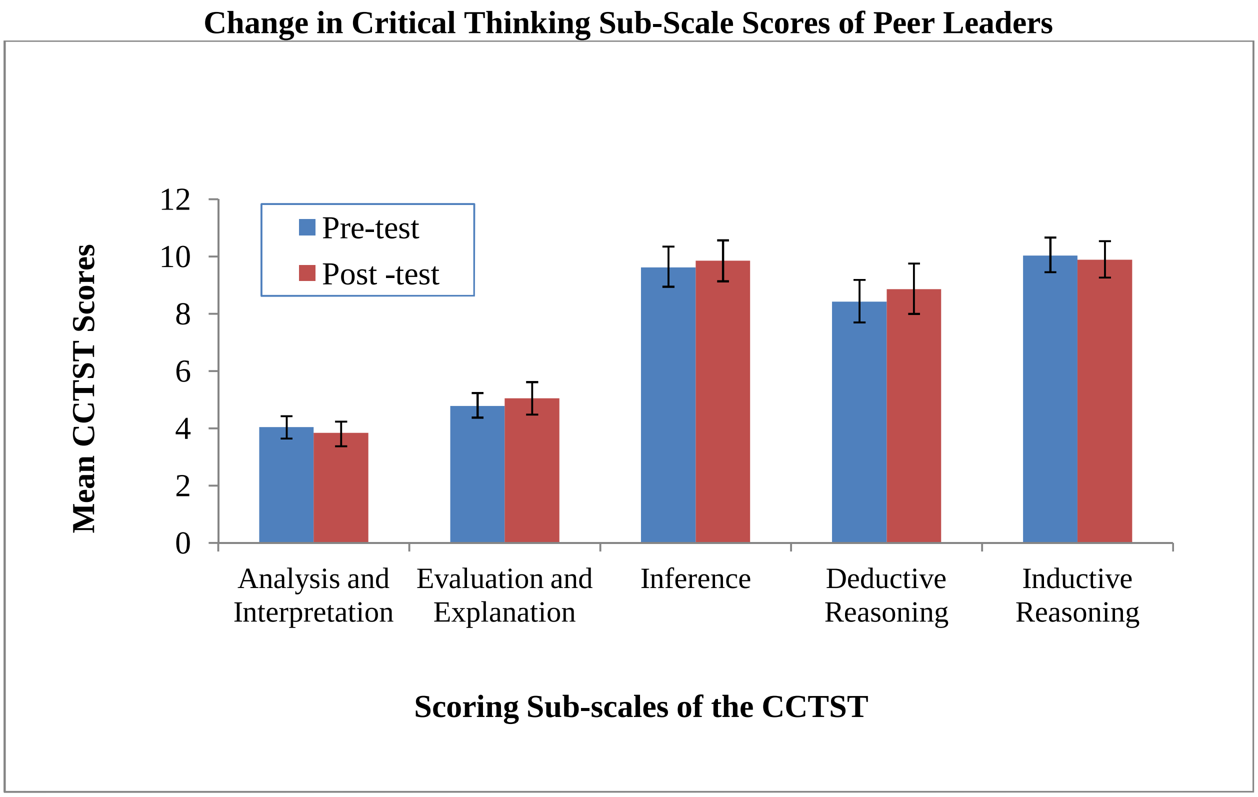


Figure 4. Mean CCTST sub-scale scores of the treatment group, pre- and post-test. Error bars indicate 95% confidence intervals. n=37 peer leaders.

Figure 5.

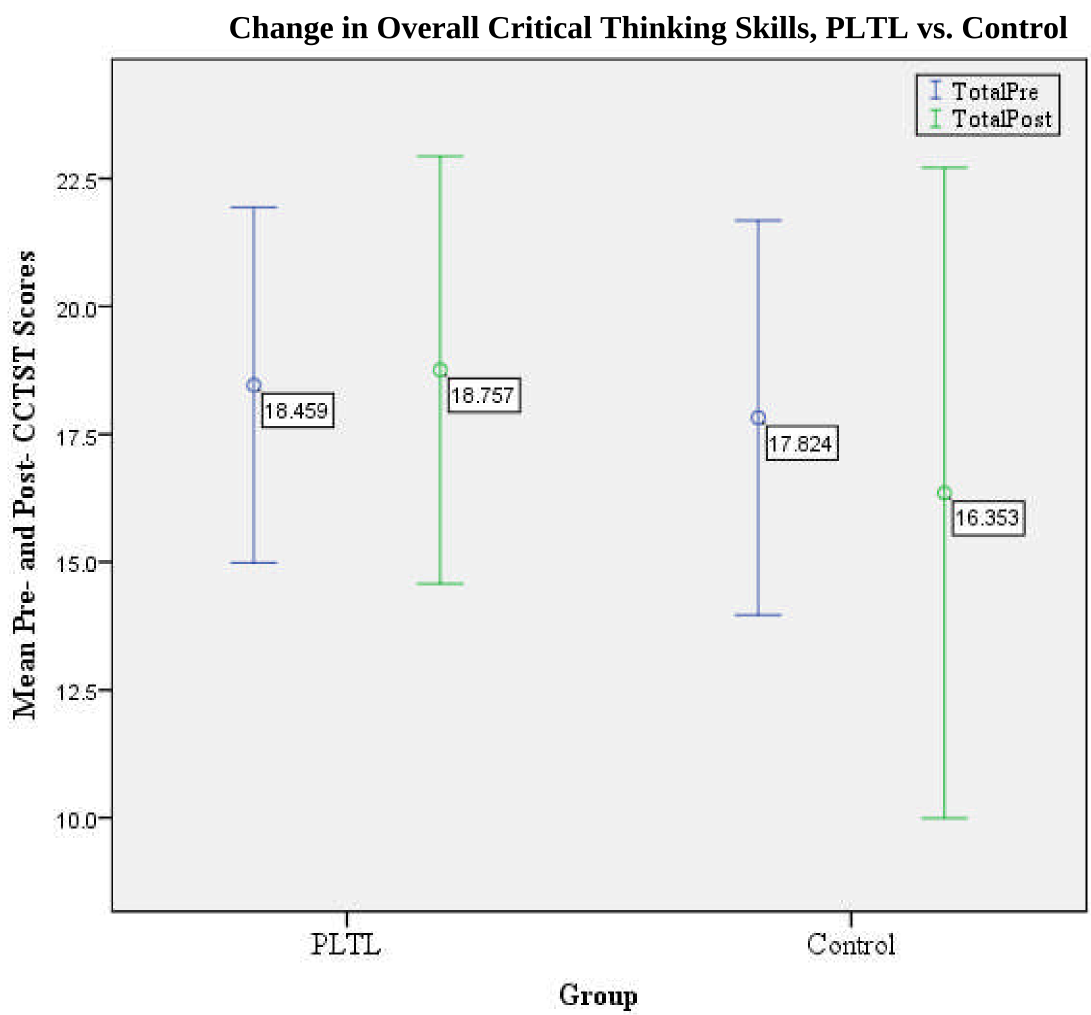


Figure 5. Change in mean CCTST scores of PLTL and Control groups from pre-test to post-test. Error bars indicate 1 standard deviation from the mean. n=37 peer leaders and n=17 control students.

Figure 6.

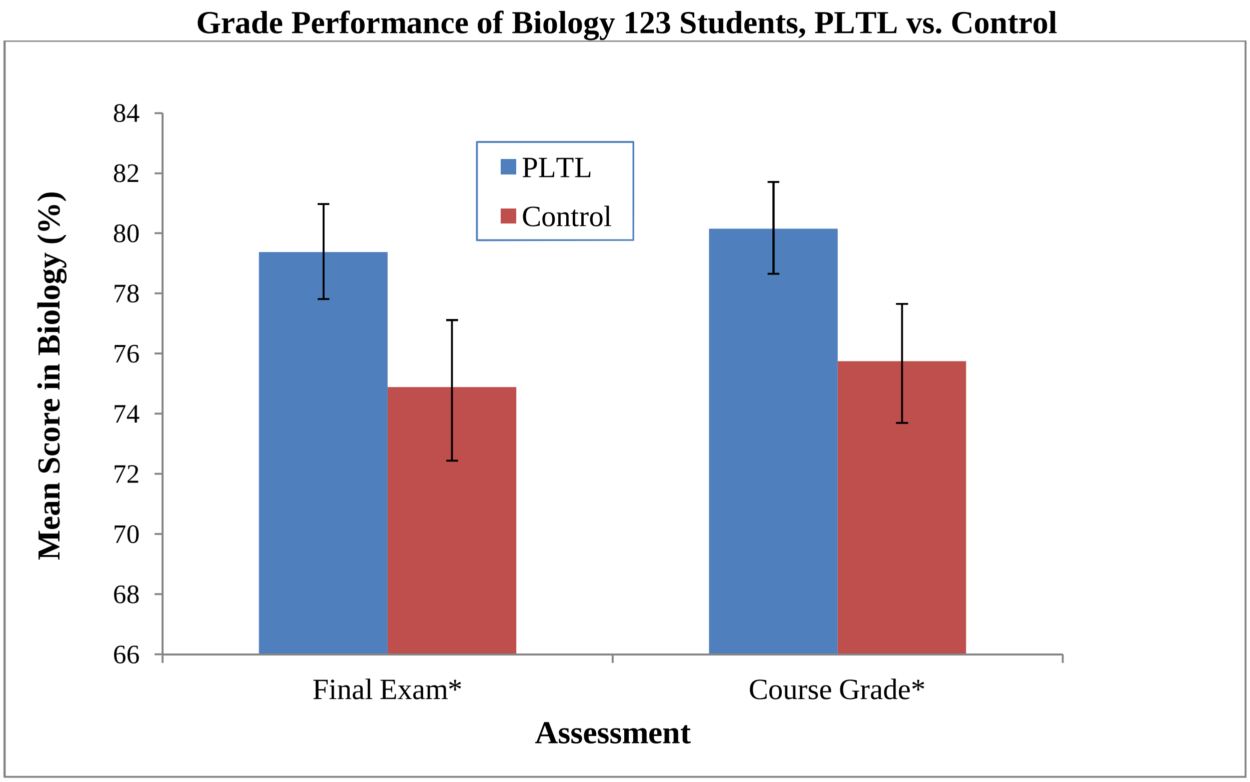


Figure 6. Mean score of final exam and final course grade of Biology 123 students, PLTL (n=136) vs. Control (n=247), during the Spring 2011 semester. Error bars indicate 95% confidence intervals. * Significant at $p < .05$.

Figure 7.

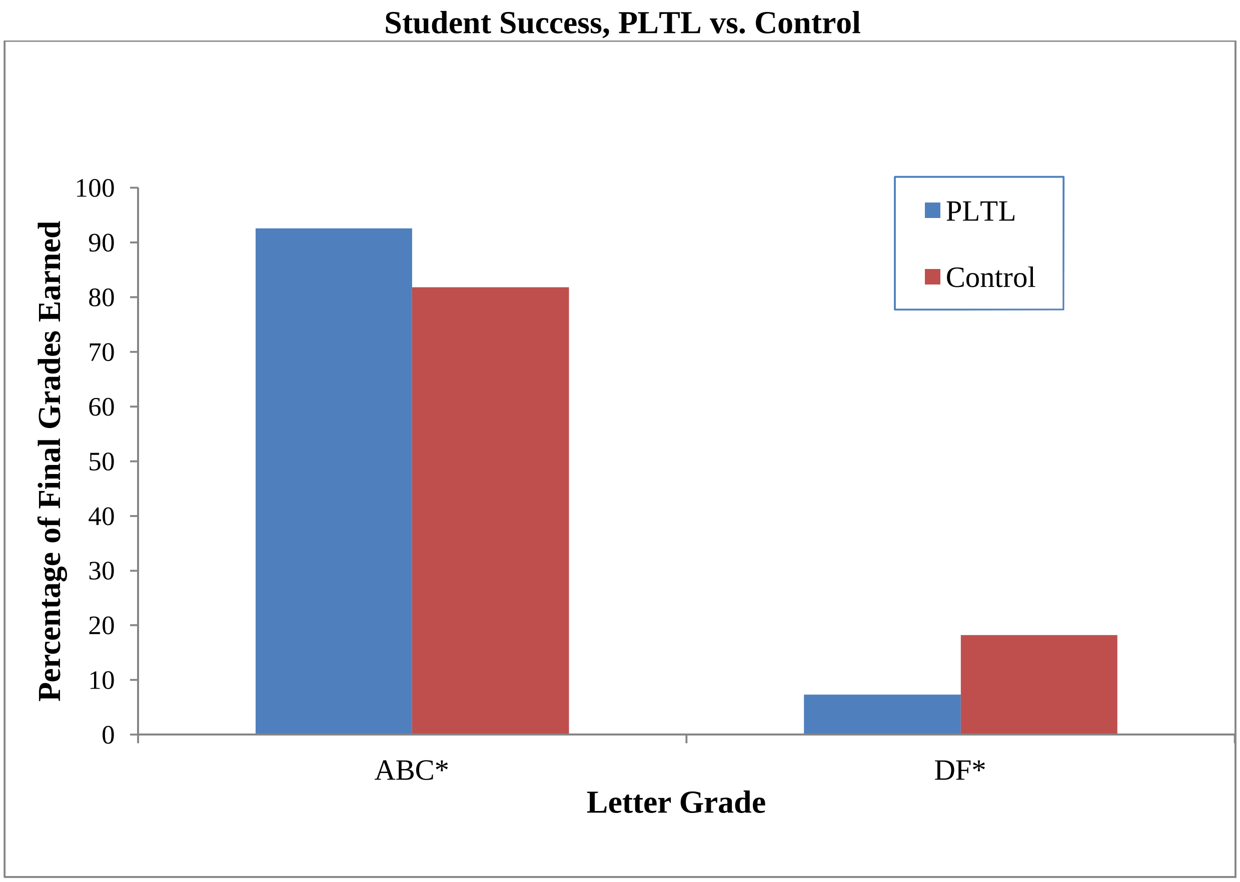


Figure 7. Percentage of Biology 123 students, PLTL (n=136) vs. Control (n=247), that earned final grades of ABC and DF during the Spring 2011 semester. Percentages of ABC and DF were calculated by summing all students with grades of C- and above and all students with grades of D or below and dividing by the total number of students enrolled in each group. *Significant at $p < .05$.

Figure 8.

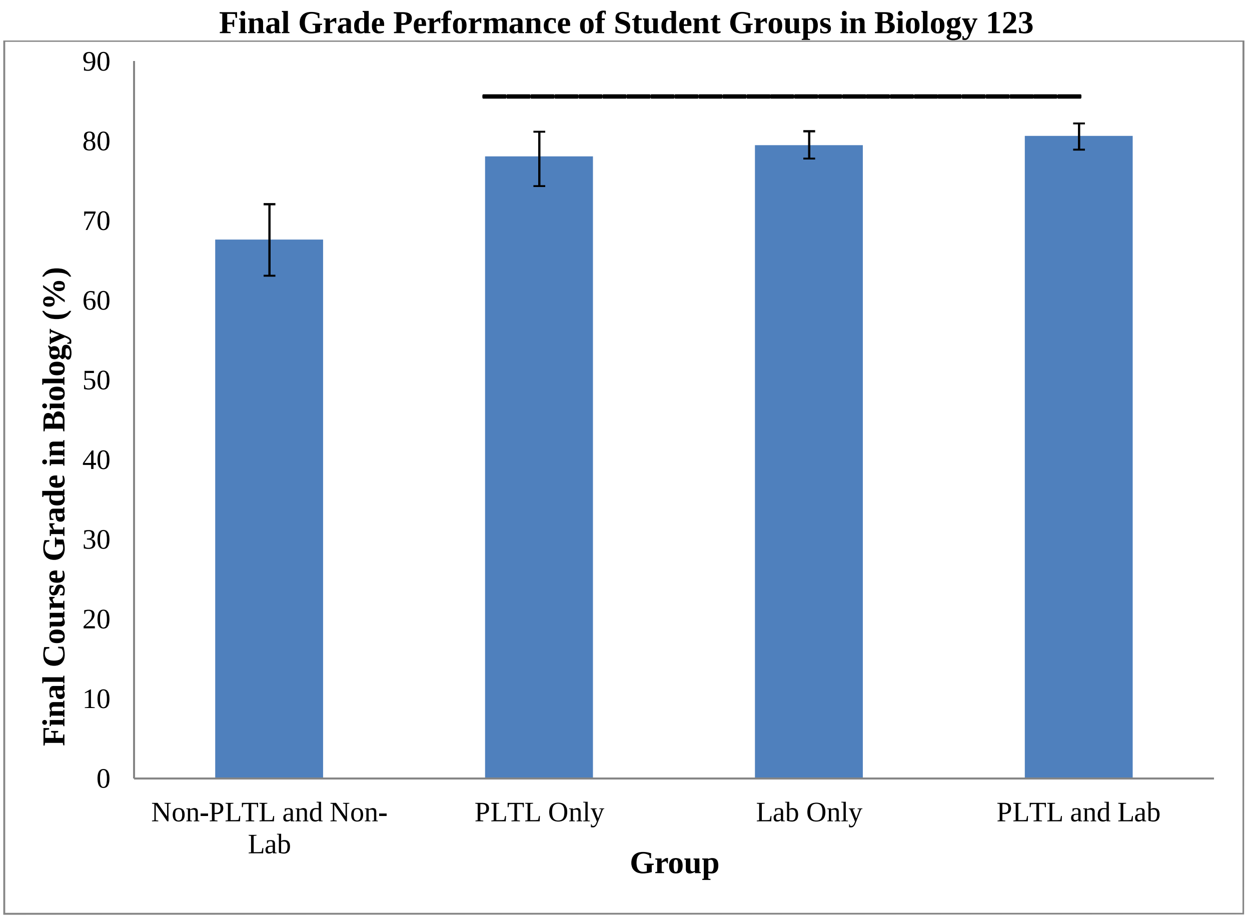


Figure 8. Mean final course grade of Biology 123 students during the Spring 2011 semester. Line over bars indicates groups which were not significantly different (Tukey's HSD, $p < .05$). Error bars indicate 95% confidence intervals; n=78 Non-PLTL and Non-Lab, n=26 PLTL Only, n=169 Lab Only, and n=110 PLTL and Lab.

Figure 9.

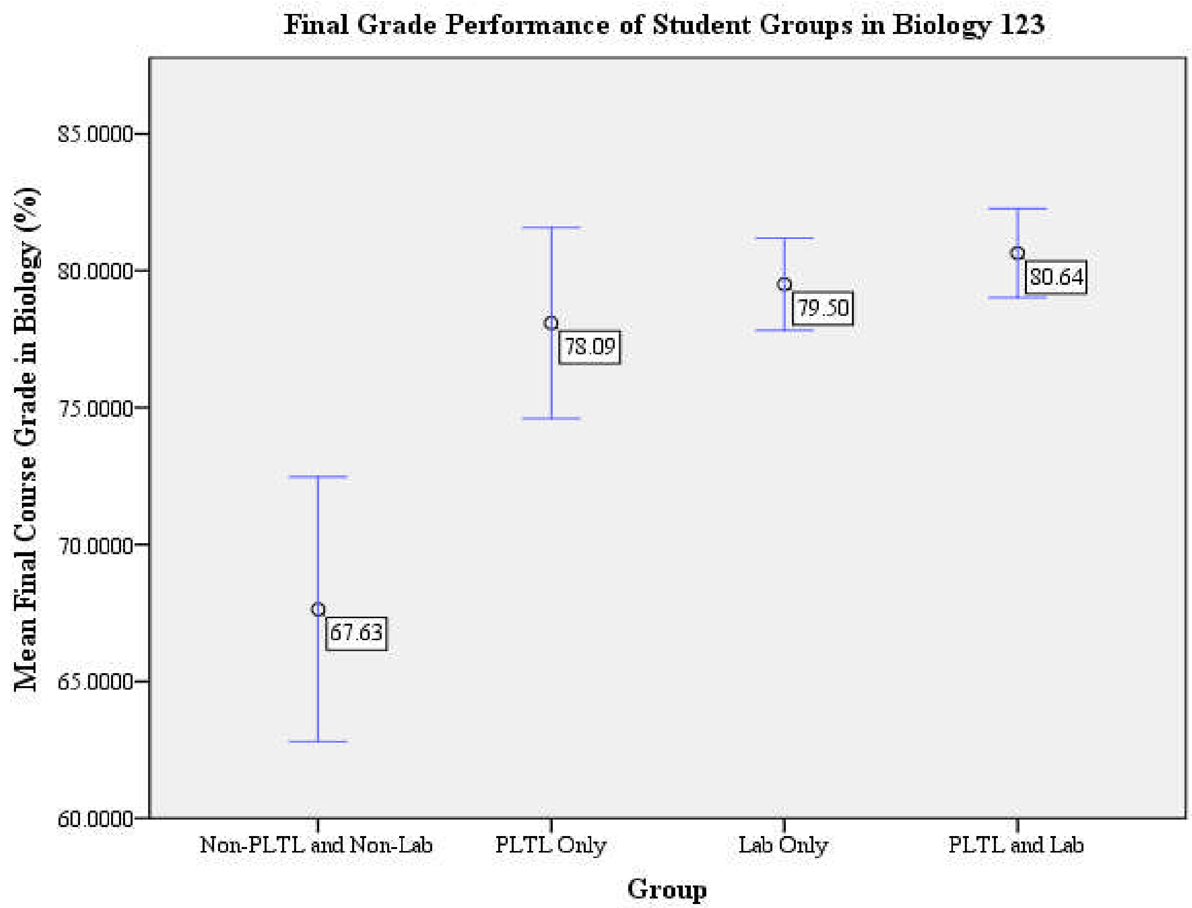


Figure 9. Mean final course grade of various groups in Biology 123 during the Spring 2011 semester. Error bars indicate 95% confidence intervals; n=78 Non-PLTL and Non-Lab, n=26 PLTL Only, n=169 Lab Only, and n=110 PLTL and Lab.

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Curriculum Vitae

Julia J. Snyder
East Syracuse, NY

EDUCATION

Doctor of Philosophy in College Science Teaching 2012
College of Arts and Sciences
Syracuse University, Syracuse, NY

Graduate Certificate in University Teaching 2012
Biology Department & Graduate School
Syracuse University, Syracuse, NY

Master of Science in Science Teaching 2001
School of Education
Syracuse University, Syracuse, NY

Bachelor of Science in Environmental Forest Biology 1999
SUNY Environmental Science and Forestry, Syracuse, NY

RESEARCH EXPERIENCE

Cengage Learning 2012-Present
Independent Consultant/Researcher

Doctoral Research (academic advisor: Dr. Jason R. Wiles) 2009-2011
Dissertation Research Project: Peer-Led Team Learning in Introductory Biology-Effects on Critical Thinking Skills

PUBLICATION

Peer-reviewed article:
Dotger, S., Barry, D., Wiles, J. R., Benevento, E., Brzozowski, F., Hurtado, J. L., Jacobs-McDaniels, N. L., Royse, E., Ruppel, R, Sen, D., **Snyder, J**., Stokes, R., & Wisner, E. Developing graduate students' knowledge of Hardy Weinberg equilibrium through lesson study. *Journal of College Science Teaching*. (Accepted 02/15/2012).

AWARDED RESEARCH FUNDING

Marvin Druger Travel Grant. J. Snyder. Syracuse University: Department of Science Teaching. $600. 2011.

Doctoral Research Funds. J. Snyder. Awarded from Renee Crown Honors College. $1000. 2011.

REFERREED CONFERENCE PRESENTATIONS

Snyder, J. J. & Wiles, J.R. (2011). Peer-Led Team Learning in Introductory Biology: Effects on Critical Thinking Skills. Presented at the Annual NABT Professional Development Conference. Anaheim, CA.

Snyder, J. J. & Wiles, J.R. (2012). Efficacy of a peer-led team learning model in introductory biology. Presented at the Ninth Annual Biology Leadership Conference. Kiawah Island, SC.

TEACHING EXPERIENCE

Graduate Teaching Assistant, Department of Biology — 2001-2005; 2008-Present
Syracuse University

Instructor, Department of Biology — 2011
Syracuse University

Guest Lecturer, Department of Biology — 2011
Syracuse University

Health 12 Teacher — 2007-2010
Living Word Academy

Living Environment Teacher — 2001-2002; 2004-2006
Cicero-North Syracuse High School

Essentials of Earth Science Teacher — 2002-2004
Cicero-North Syracuse Junior High School

Graduate Teaching Assistant, Department of Science Teaching — 1999-2000
Syracuse, NY

Undergraduate Teaching Assistant, Department of Biology — 1997
SUNY Environmental Science and Forestry

SUBJECTS TAUGHT

UNDERGRADUATE: Introductory Biology Laboratory I & II, Introductory Biology I & II (Guest Lectures), Biology Special Topics: Peer-Led Team Learning Leadership Experience, Anatomy and Physiology (Guest Lectures), Dendrology

SECONDARY: Living Environment, Essentials of Earth Science, Health 12

RELATED PROFESSIONAL EXPERIENCE

- **Future Professoriate Program**. Syracuse University. 2008-2012
  *Independent Teaching Experience***.** Held primary responsibility for my own course, under the guidance of a faculty teaching mentor.

- **Syracuse University Project Advance**. Syracuse, NY. 2010-2011
  Professional Development Workshops. Worked with secondary level teachers to explain various biology lab and recitation concepts.

- **Sinauer Associates, Inc**. Sunderland, MA. 2009-2010
  Reviewer. Reviewed test files and animations that supported the 9^{th} Edition of Life: The Science of Biology.

- **Cicero-North Syracuse Schools**. North Syracuse, NY. 2005-2006
  Modified Cross Country Assistant Coach. Worked with middle school runners on proper stretching, running form and techniques, and racing strategies.

- **Private Tutor.** Cazenovia, NY**.** 2004
  *Math and Science Tutor***.** Conducted one-on-one math and science tutoring sessions with a middle school student.

- **Bristol Meyers Squibb Science Horizons**. Syracuse, NY. 2000-2001
  Graduate Student Leader. Led middle school science students through various science activities during the weeklong summer program, as well as designed and conducted various science activities for the students.

AWARDS

National Association of Biology Teachers Four-Year College Section Vernier Student Travel Award 2011

Maple Leaf Award 1998

PROFESSIONAL MEMBERSHIP

National Association of Biology Teachers 2011-Present