Supplemental Action Learning Workshops: Understanding the Effects of Independent and Cooperative Workshops on Students’ Knowledge

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SUPPLEMENTAL ACTION LEARNING WORKSHOPS: UNDERSTANDING THE EFFECTS OF INDEPENDENT AND COOPERATIVE WORKSHOPS ON STUDENTS’ KNOWLEDGE

by

Kathryn Michelle Morris

A Dissertation
Submitted to the Graduate School
and the Center for Science and Mathematics Education
at The University of Southern Mississippi
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for the Degree of Doctor of Philosophy

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ABSTRACT

SUPPLEMENTAL ACTION LEARNING WORKSHOPS: UNDERSTANDING THE EFFECTS OF INDEPENDENT AND COOPERATIVE WORKSHOPS ON STUDENTS’ KNOWLEDGE

by Kathryn Michelle Morris

May 2016

Community colleges enroll more than half of the undergraduate population in the United States, thereby retaining students of varying demographics with extracurricular demands differing from traditional four-year university students. Often in a collegiate lecture course, students are limited in their abilities to absorb and process information presented by their instructors due to content-specific cognitive gaps between the instructor and the student (Preszler, 2009). Research has shown that implementation of instructor-facilitated action learning workshops as supplemental instruction may help bridge these cognitive gaps allowing better student conceptualization and dissemination of knowledge (Drake, 2011; Fullilove & Treisman, 1990; Preszler, 2009; Udovic, Morris, Dickman, Postlethwait, & Wetherwax, 2002).

The purpose of this study was to determine the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge of specified topics within a General Biology I with lab course. The results of this investigation indicate that implementation of an instructor-facilitated action learning workshop did not affect students’ knowledge gain; furthermore, attendance of a particular workshop style (independent or cooperative) did not affect students’ knowledge gain.
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DEDICATION

I dedicate this work to Zacharias H. McClendon, whose friendship will forever be cherished, though our time together was brief. His passion for life and education was truly inspirational, and I thank him for rekindling a similar passion within me.

I am grateful to my family and friends for their continued encouragement throughout this journey. I would like to thank my parents, Ed and Linda Morris, for instilling within me the importance of education and hard work and for their continued love and support. I would like to thank my brother and sister-in-law, Steven and Heather Morris, for continued support and encouraging words. To my colleague and dear friend, Dr. Erin Riggins, who is the person responsible for recruiting me to join her in the venture and, at times, had to drag me through while kicking and screaming, I could not have done it without her. I thank her for her continued support, guidance, and motivation, as well as some memorable car rides to and from school. I would like to thank Jeff Bauman for saving my hard drive when it crashed long enough to retrieve my first dissertation draft. To my friends, Dr. Kelly Rouse and Dr. Rachel Ryan, for listening to presentation practices and for being a shoulder to lean on for advice, their guidance and insight was invaluable. I would also like to thank Amanda and Andrew Claxton and Lora and Austin Townsend for their continued support and for helping cut manipulatives and listening to me practice my presentations. Finally, I would like to thank Michael McKinney for not only reading and providing grammatical and punctuational advice but also for his continued support and confidence in my abilities to excel in whatever journey I pursue.
# TABLE OF CONTENTS

ABSTRACT .................................................................................................................. ii

ACKNOWLEDGMENTS ............................................................................................... iii

DEDICATION ................................................................................................................. iv

LIST OF TABLES .......................................................................................................... viii

LIST OF ILLUSTRATIONS ........................................................................................... ix

CHAPTER I - INTRODUCTION .................................................................................... 10

Community College Demographics ........................................................................... 10

Statement of the Problem .......................................................................................... 12

Research Questions and Hypotheses ......................................................................... 12

Definition of Terms .................................................................................................... 13

Delimitations ............................................................................................................... 15

Limitations and Discussion ....................................................................................... 16

Assumptions ............................................................................................................... 16

Justification of the Study .......................................................................................... 16

CHAPTER II – REVIEW OF RELATED LITERATURE .................................................. 18

Introduction ............................................................................................................... 18

Theoretical Foundation: Workshops as Supplemental Instruction ............................. 20

Conceptual Framework: Action Learning Theory ...................................................... 22

Rationale for the Study .............................................................................................. 25
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>III</td>
<td>METHODOLOGY</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Research Questions</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Research Design</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Participants</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Instrumentation</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Procedure</td>
<td>31</td>
</tr>
<tr>
<td>IV</td>
<td>ANALYSIS OF DATA</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Findings</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Research Hypothesis One</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Research Hypothesis Two</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Research Hypothesis Three</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>48</td>
</tr>
<tr>
<td>V</td>
<td>DISCUSSION</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Summary of the Study</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Description of Sample Participants</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Description of Study Variables</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Analysis of Research Questions and Hypotheses</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Research Question One</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td></td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1 Total Participation for Control Group ................................................................. 39
Table 2 Total Participation for Experimental Group .......................................................... 39
Table 3 Basic Descriptives for Topics 1-4 ........................................................................ 40
Table 4 Descriptives for Learning Styles ......................................................................... 41
Table 5 Levene’s Test for Homogeneity of Variance ......................................................... 43
Table 6 Mean Pretest, Mean Posttest, and Mean Gain Score per Topic ............................. 43
LIST OF ILLUSTRATIONS

*Figure 1.* Illustration of the challenges educators face when addressing the two main groups of students ................................................................. 18

*Figure 2.* Relationship among instructor facilitated supplemental instruction and student outcomes ................................................................. 20

*Figure 3.* Workshop tree model summarizing the workshop layout and design. .......... 34

*Figure 4.* Comparison of mean test scores from Topic 1 and learning styles for control and experimental groups.................................................. 46

*Figure 5.* Comparison of mean test scores from Topic 2 and learning styles for control and experimental groups.................................................. 47

*Figure 6.* Comparison of mean test scores from Topic 3 and learning styles for control and experimental groups.................................................. 47

*Figure 7.* Comparison of mean test scores from Topic 4 and learning styles for control and experimental groups.................................................. 48
CHAPTER I - INTRODUCTION

Community colleges enroll 51.6 %, more than half, of the undergraduate population in the United States, thereby retaining students of varying demographics with extracurricular demands differing from traditional four-year university students, which make these institutions significant players in providing foundational coursework for becoming scientifically literate (National Education Association [NEA], 2013). Scientific literacy among students is a growing concern as the number of students who are prepared in a manner conducive for success in collegiate science courses has declined (Belzer, Miller, & Shoemake, 2003). Although scientific literacy is difficult to define, Holbrook and Rannikmae (2009) state that two major aspects remain consistent: (1) the acquisition and role of scientific knowledge; and (2) its social applications. While the reasons for developing scientific literacy among students majoring in the field appears obvious, the reasons for non-majors may be debated. Regardless of whether a student is a major or a non-major, the main goal of science education, with respect to the development of scientific literacy, is to create individuals capable of delineating sense from nonsense, as well as, cultivate important skills such as critical thinking and problem solving, which may be extrapolated and applied to all aspects of life (Bybee, 1997). Having scientifically literate individuals create members of society who are better equipped for judging scientific claims (Feinstein, Allen, & Jenkins, 2013).

Community College Demographics

Community colleges are an integral component of the educational system as they display a growing diversity in the student population (Biermann, 1996; Phillippe & Sullivan, 2005). According to data collected from the National Science Foundation’s
2001 National Survey of Recent College Graduates, on average, 44% of science and engineering graduates attend community colleges (Tsapogas, 2004). Community college student populations differ from traditional four-year university student populations in socioeconomic status, age, vocational goals, ethnicity, and social status, as reflected by most of these institutions’ open-door policies (Marcus, 1993). A major hallmark of community colleges has been flexibility by offering various class schedules to accommodate a pace that may fit the busy lives of students who may have work obligations and family commitments (Phillippe & Sullivan, 2005).

Often in a collegiate lecture course, students are limited in their abilities to absorb and process information presented by their instructors due to content-specific cognitive gaps between the instructor and the student (Preszler, 2009). Although instructors are best positioned to deliver course content, they may not provide the most accessible portals of entry to the discipline for most students (Preszler, 2009). For example, a student taking a course from an instructor who teaches using the Socratic Method may not understand the information the instructor is trying to relay, even though the instructor is knowledgeable; an instructor who teaches using visual aids and/or animations may relay the information in a manner that student is capable of receiving. Undergraduate academic workshops based on action learning, learning by doing, may lead to opening portals of entry to the discipline as well as address the hallmark of responding to student needs.

Various studies (Douglas & Machin, 2004; Drane, Smith, Light, Pinto, & Swarat, 2005; Duncan & Dick, 2000) have provided support suggesting that workshop programs appear to be successful within science in both academic enhancement and retention. Perhaps this serves as an indication that students entering undergraduate science courses
need extra time with a facilitator to grasp a foundation needed to continue towards earning a degree. Workshops, as supplemental teaching aids, are a fairly new method for generating knowledge, learning, and dissemination, thereby allowing for instruction outside of the classroom environment for students needing further guidance with a specific concept and/or idea; these workshops may be a valuable teacher aid allowing students with varying learning styles an environment open to exploration.

Statement of the Problem

The purpose of this study was to determine the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge of specified topics within a General Biology I with lab course. This study also attempted to determine whether there was a difference in students’ knowledge between the two different workshop styles.

Research Questions and Hypotheses

Overarching Research Question: Does knowledge of four topics covered in a General Biology I with lab course differ between student populations who attend an action learning workshop versus those who do not attend an action learning workshop?

Specific Research Question One: How does students’ knowledge change following an action learning workshop?

- Research Hypothesis One: There will be a significant difference between the scores on the pre-workshop test and post-workshop test.

Specific Research Question Two: Was there a difference in students’ knowledge between the independent action learning and the cooperative action learning workshop?
• Research Hypothesis Two: There will be a significant difference when comparing pre-/post-test scores of those who attend the independent action learning workshop versus the pre-/post test scores of those who attend the cooperative action learning workshop.

Specific Research Question Three: Does students’ learning styles affect the knowledge gained?

• Research Hypothesis Three: There will be a significant difference in a students’ learning style, delineated from their VARK questionnaire, and the knowledge gained.

Definition of Terms

The following terms are used in this study and should be understood in their complete context.

• Action Learning: Often synonymous with experiential learning, this type of learning focuses on learning from concrete experience and critical reflection on that experience through various means (Johnson, Wardlow, & Franklin, 1997; Kolb, 1984; Zuber-Skerritt, 2002). This type of environment allows students the opportunity for discovery through application of a concept to real world scenarios, engaging students in experiential learning via hands-on, application-oriented activities (Brooks & Brooks, 1993; Johnson et al., 1997; Saitta, Gittings, & Geiger, 2011; Zuber-Skerritt, 2002).

• Aural Learner: An individual who concentrates on listening to the words given by the teacher and prefer participating in discussions and listening to recorded lectures (Prithishkumar & Michael, 2014).
• Conceptual Understanding: The implicit or explicit understanding of governing principles and the ability to disseminate relationships within and/or among those principles (Payne, Mendonça, Johnson, & Starren, 2007; Rittle-Johnson, Siegler, & Alibali, 2001).

• Cooperative Action Learning Workshop: A workshop style that provides an environment conducive to the exploration, visualization, and application of topics by engaging students in small groups that fosters discussion and the ability to learn from one another’s ideas while ultimately requiring the student to take responsibility for his/her own learning (Hernández, 2012; Slavin, 1980).

• Cooperative Learning: A type of learning, often considered the heart of problem-based learning that allows students the ability to work together, cooperatively, to accomplish shared learning goals (Johnson, Johnson, & Smith, 1998).

• Dimensional Analysis: A problem solving strategy that is a useful tool to guide students through a series of calculations, while allowing them to keep track of units, from a given unit of measure to an unknown unit of measure (Saitta et al., 2011).

• Independent Action Learning Workshop: A workshop style that provides an environment conducive to the exploration, visualization, and application of topics by engaging students independently from one another, fostering the ability to use one’s own ideas while ultimately requiring the student to take responsibility for his/her own learning.
• Kinesthetic Learner: An individual who prefers hands-on experiences, practical applications, model usage, and real life scenarios (Prithishkumar & Michael, 2014).

• Knowledge: From a constructivism perspective, knowledge is the information that is actively built by the learner (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

• Read/Write Learner: An individual who gains information best when reading textbooks, notes, or supplemental handouts (Prithishkumar & Michael, 2014).

• Visual Learner: An individual who learns by looking at visual cues such as images and figures, graphics, and videos (Prithishkumar & Michael, 2014).

• Workshops: In general, these are academic structures of learning and knowledge dissemination capable of being incorporated as teaching aids that allow for the exploration of a particular set of concepts and/or ideas (Rogers, 2009).

• Process Workshops: Workshops specifically designed to mimic a classroom environment with an emphasis on student engagement whereby students are given activities involving guided discovery, critical thinking, and problem solving (Hanson & Wolfskill, 2000).

Delimitations

The results of this study are delimited to the particular students who were enrolled in face-to-face General Biology I with lab courses at a southern community college during the fall 2015 semester; therefore, this study may not be universally applied beyond this student population. Student participants of this study varied in major, age, ethnicity, and gender; therefore, they were not distributed equally. The participants completed the VARK questionnaire, pretests, and posttests for homework or as classwork assignments.
Limitations and Discussion

The results of this study are limited to community college students enrolled in face-to-face biology courses effort during the fall 2015 semester in completing all pretests, posttests, questionnaires and workshop attendance. These students were of varying majors, and were not distributed equally by age, gender, nor ethnicity. Also, instructors for the courses were not constant as the participants were selected from several biology courses from different campuses of the institution; therefore, students may have been paced differently as to when the lecture was given for a particular topic. Finally, all pretests were given at the beginning of the semester while each posttest was given the same day students took the in class exams covering those particular topics.

Assumptions

It was assumed that students answered the questionnaire, pretest, and posttest questions to the best of their abilities. It was possible that students may not answer pretest and posttest questions thoughtfully or could allow someone else to answer questionnaires for them since they will be distributed online. It was also assumed that all students should show a gain score when comparing pretest and posttest scores regardless of attending a workshop.

Justification of the Study

Though research exists supporting the implementation of academic workshops for increasing students’ knowledge among the sciences, there is a gap in the literature on workshops as teaching aids on specific topics covered in general biology courses with regards to effective styles when applying action learning. Also, existing research on action learning is assumed to be taking place within a cooperative environment; however,
there lies a gap in literature on the delineation of action learning within an independent setting. This poses the question: how much of students’ knowledge gain comes from merely navigating action through activities and how much knowledge gain depends on the interaction from peers within the cooperative setting?
CHAPTER II – REVIEW OF RELATED LITERATURE

Introduction

Community colleges enroll two main groups of students according to Cross (1980): “new” students and “nontraditional” students. “New” students are defined as those entering higher education ill-prepared, requiring added assistance with basic skills, motivation, and guidance in navigating the educational system, thereby placing one at an educational disadvantage (Cross, 1980). “Nontraditional” students are considered adult learners who tend to be independent in thought and self-directed, wanting to be in control of their learning and often with increased extracurricular stressors (e.g. family, jobs, or other obligations) (Cross, 1980; Knowles, 1980). Educators within the community college system have the challenge of teaching two distinct groups of learners, thereby forcing educators to engage in a variety of teaching methods in order to meet the needs, which are drastically different, of these two groups (Cross, 1980). Figure 1 illustrates the balancing act that educators face in addressing the two groups of students.

![Figure 1](image)

*Figure 1.* Illustration of the challenges educators face when addressing the two main groups of students

(Cross, 1980; Knowles, 1980).
Knowles (1973) advocated the need for an andragogical, or adult-centered, approach for teaching, focused around creating a climate centered on mutual trust and clarification of expectations, essentially fostering a form of cooperative and collaborative learning (Russell, 2006). When it comes to describing adult learners, there are five assumptions underlying andragogical approaches: (1) adult learners have an independent self-concept and are capable of directing their learning, (2) they have accumulated years of life experiences which can serve as a reservoir for learning, (3) they have learning needs that are reflected in changing social roles, (4) they tend to be concerned with problem-solving and the ability to apply knowledge, and (5) they are intrinsically motivated to learn (Knowles, 1973; Merriam, 2001). Cooperative and collaborative learning are commonly used interchangeably though connotatively different (Oxford, 1997). In recent years, collaborative learning acculturates the learners into knowledge communities using social constructivism as the foundation (Oxford, 1997). Dewey (1916) was a pragmatist advocating the social process of education through incorporation of an ongoing activity as being more important than knowledge alone. Vygotsky is another constructivist who acknowledged the importance of communication within social groups on an individual’s cognitive system, viewed teachers as a facilitator available for providing assistance and guidance while allowing the student to take control of their learning (Oxford, 1997).

While supplemental instruction (SI) is traditionally defined as being a peer-led academic program allowing students to participate in an open cooperative and collaborative environment aimed at facilitating student learning, Drake (2011) suggests the importance of creating instructor-led programs (Shaya, Petty, & Petty, 1993; Udovic
et al., 2002). Instructor-facilitated SI has shown to provide students additional benefits over traditional SI models in that students who attended instructor-led SI programs received higher exam scores, were more detail-oriented in their work, had more meaningful interactions with the instructor, and appeared to exhibit more academic self-confidence (Drake, 2011). These effects are summarized in Figure 2.

Figure 2. Relationship among instructor facilitated supplemental instruction and student outcomes

(Plake, 2011).

Theoretical Foundation: Workshops as Supplemental Instruction

Workshops, in general, are academic structures of learning and knowledge dissemination capable of being incorporated as teaching aids that allow for exploration of a particular set of concepts and/or ideas (Rogers, 2009). The use of workshops as teaching aids is a fairly new method for generating knowledge, learning, and dissemination outside of the lecture classroom for students who need further guidance with a specific concept and/or idea; these workshops may be a valuable teacher aid allowing students with varying learning styles in an environment open to exploration (Drake, 2011; Hanson & Wolfskill, 2000; Prezler, 2009; Udovic et al., 2002).

A study conducted by Uri Treisman at the University of California, Berkeley, explored the performance of two groups of students, 20 African Americans and 20 Chinese Americans, enrolled in introductory calculus (Fullilove & Treisman, 1990). Treisman found that the two groups of students’ success were significantly and sharply
contrasting; the Chinese American students excelled while many of the African American students failed (Duncan & Dick, 2000). The study revealed the difference between how these two groups viewed the meaning of *studying math*. Treisman also noted that the Chinese American students often met in peer study groups, while the African American students tended to work in isolation rarely collaborating with others. The results of this study led Treisman toward the development of the Mathematics Workshop Program designed for providing students enrolled in introductory calculus supplementary peer collaborative problem solving experiences (Duncan & Dick, 2000). Since the development of this workshop program, other disciplines have used Treiman’s model as a template for designing collaborative workshops to support classroom instruction. Studies have been conducted within the sciences, specifically in the areas of Biology, Chemistry, and Physics.

Udovic et al. (2002) developed The Biology Workshop project in hopes of improving science literacy among non-science majors at the University of Oregon. Students who participated in the workshop responded to a questionnaire with responses that were lengthy and well thought out, indicative of an improved ability to reflect critically on their learning (Udovic et al., 2002). Student participants of collaborative workshop-like supplemental instruction displayed significant improvement in conceptual learning and understanding, a greater appreciation of science, and greater motivation as well as involvement in activities. Preszler (2009) implemented mandatory peer-led workshops in an introductory biology course designed for majors, and the results indicated a significant increase in student semester grades. Furthermore, the results indicated an enhancement in the quality of learning taking place; that is students not only
showed a 45% increase in the number of A’s and B’s earned but they also developed higher level thinking skills, enabling them to answer conceptually challenging questions on examinations (Preszler, 2009). Whether supplemental collaborative learning takes on the name “workshop” or “assembly,” these collaborative approaches to learning are beneficial to students, offering them an opportunity for meaningful learning that develops a stronger sense of academic self-confidence as well as improving grades (Drake, 2011; Udovic et al., 2002).

Process workshops, defined by providing a classroom environment with active engagement in learning, have proven to increase students’ critical thinking skills by allowing students to discover concepts through the execution of guided activities (Hanson & Wolfskill, 2000). Process workshops incorporate the use of manipulatives, tangible materials, which allow students to connect abstract concepts and/or ideas with concrete objects through experiences using the manipulatives (Saitta et al., 2011; Uttal, Scudder, & DeLoache, 1997).

Conceptual Framework: Action Learning Theory

Action learning involves learning about learning and can have multiple definitions; however, for the purpose of this study, action learning will focus on experiential learning, or learning by doing (Johnson et al., 1997; Zuber-Skerritt, 2002). Programs outside the realm of formal education, such as scouting and 4-H, have implemented this notion of experiential learning nearly a century ago. Research has advocated that the implementation of action learning paradigms within these organizations have the potential to be more effective learning experiences in that leaders’ roles are more hands-on (Kleinfeld & Shinkwin, 1983). Kleinfeld and Shinkwin (1983)
go on to explain that what happens educationally is directly proportional to the abilities of
the leader as well as the degree of involvement, thereby insinuating a more guided
approach to discovery. Experiential learning is derived from the constructivist approach,
delineating the necessity for concrete physical experiences in learning scientific
principles and concepts (Brooks & Brooks, 1993; Dewey, 1938; Kolb & Kolb, 2005).
The idea of experiential learning is driven by a process created through the
transformation of experience, thereby resulting in knowledge (Kolb, 1984). Action
learning, or experiential learning, provides students with a hands-on, application-oriented
activity thereby reinforcing scientific principles and concepts (Johnson et al., 1997; Saitta
et al., 2011; Zuber-Skerritt, 2002).

Action learning, when used in former research, assumes that the experience is
taking place within some sort of collaborative and/or cooperative group setting. While
the terms are typically used interchangeably, there is a distinguishable difference between
the two. Collaborative learning by means of action learning is a way of engaging students
by creating a group environment that provides freedom needed to explore a concept so
that the entire group works toward a specific outcome. (Hernández, 2012). Cooperative
learning incorporates this same group environment; however, though the group is
working toward a similar outcome, each individual is responsible for learning the concept
and perhaps teaching material to other members within that group. Though collaborative
learning offers a natural social environment in which learning can take place, cooperative
learning is more appropriate for this study as it provides students the opportunity to work
together, cooperatively, in order to accomplish shared learning goals while also holding
the individual accountable for learning, thereby making it a more favorable avenue for
pursuing problem-based learning (Johnson et al., 1998). Science lessons are notorious for requiring students to have a deep understanding of concepts and/or ideas requiring critical thinking skills in order to fully understand topics on a level conducive for transferring knowledge into subsequent courses, making them ideal for implementation of action learning due to the already hands-on nature of science (Franks & Jewitt, 2001). Douglas and Machin (2004) focused their research on the ‘process’ of the action learning set, their program, rather than on the ‘outcome’ of the action learning set, thereby exploring participant experiences and perceptions of being a part of such an environment as well as the learning that took place within the environment. Findings suggest that action learning may be a successful approach in capturing situational processes and deriving a model (Douglas & Machin, 2004).

Though research shows incorporation of action learning as supplemental instruction, the implementation of action learning assumes that experiential learning is taking place within a group setting (Douglas & Machin, 2004; Hernández, 2012; Saitta et al., 2011). Armbruster, Patel, Johnson, and Weiss (2009) hypothesized that implementation of active-learning and student-centered pedagogy into the instructional design of an introductory Biology II course would both improve student attitudes and thereby lead to increased student performance. Results revealed that the addition of an active learning environment significantly improved both student attitude and academic performance (Armbruster et al., 2009). Saitta et al. (2011) also implemented an action-learning environment into a Chemistry I course using an activity to help students understand the process of performing dimensional analysis. Upon analysis of the gain scores between the pretest and posttest showed that the experimental group (activity
implemented) performed significantly better than the control group (no activity implemented) (Saitta et al., 2011).

Rationale for the Study

Concerned about students’ ability to absorb and conceptualize information presented during a course lecture, instructors seek ways to compensate by implementing forms of supplemental instruction to address cognitive gaps. Several reports and articles have appeared in recent years drawing attention to the need for undergraduate science education reform promoting meaningful learning, problem solving, and critical thinking skills (Armbruster et al., 2009; Douglas & Machin, 2004; Hernández, 2012; Saitta et al., 2011). Though research has resulted in the advantages of Visual, Aural, Read/Write, and Kinesthetic (VARK) methods in areas of chemistry and physics, little has been done to explore the use of action-based student workshops in the biological science reinforcing content while engaging students in inquiry, exploration, and collaboration. Furthermore, research has been done on the effectiveness of manipulatives and activities as well as action-learning; however, much of the research involving action-learning assumes the collaborative setting. Little has been done to compare individual action (use of a manipulative, for example) to that of action-learning within the collaborative realm. This study seeks to address this gap focusing on seeing how much of a students’ knowledge of a topic relies on simply doing an activity utilizing a manipulative versus doing the activity utilizing a manipulative within a cooperative group setting.

Summary

The purpose of this study was to determine the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge
of specified topics within a general biology course. Research shows that implementation of workshops as supplemental instruction provides students the avenue for filling cognitive gaps, making them strong academic performers. Likewise, the addition of action-learning and manipulatives provides students with a hands-on visual approach to a concept, thereby also increasing conceptual understanding for dissemination of knowledge.
CHAPTER III - METHODOLOGY

Introduction

The purpose of this study was to determine the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge of specified topics within a general biology course. In this study, the overarching research question was: Does knowledge of four topics covered within a general biology course differ between student populations who attend an action learning workshop versus those that do not attend an action learning workshop?

Research Questions

The data was analyzed to address the following research questions and hypotheses:

Overarching Research Question: Does knowledge of four topics in a general biology course differ between student populations who attend an action learning workshop versus those who do not attend an action learning workshop?

Specific Research Question One: How does students’ knowledge change following an action learning workshop?

- Research Hypothesis One: There will be a significant difference between the scores on the pretest and posttest of those who did not attend a workshop versus those who did attend a workshop. The hypothesis above was tested for each workshop offered on Topics 1-4.

Specific Research Question Two: Was there a difference in students’ knowledge between the independent action learning and the cooperative action learning workshop?
• Research Hypothesis Two: There will be a significant difference when comparing pretest and posttest scores of those who attend the independent action learning workshop versus the pre-/post-test scores of those who attend the cooperative action learning workshop. The hypothesis above was tested for each workshop offered on Topics 1-4.

Specific Research Question Three: Does students’ learning styles affect the knowledge gained?

• Research Hypothesis Three: There will be a significant difference in a students’ learning style, delineated from their VARK questionnaire scores, and the knowledge gained. The hypothesis above was tested for each workshop offered on Topics 1-4.

Research Design

A quantitative quasi-experimental approach was undertaken to answer the above research questions. The participants, requirements of the study, and the design of each instrument were kept constant so as not to influence results. Although the courses were taught by different instructors, the constancy of research design ensured the capture of the effect of the style of workshop, independent or cooperative, on knowledge.

At the beginning of the semester, and after receiving permission from the University of Southern Mississippi’s Institutional Review Board and the community college in which the study was performed, students were recruited from fourteen face-to-face General Biology I with lab courses. The participants in the face-to-face General Biology I with lab courses who did not attend a workshop were considered the control group while the students who attended a workshop were considered the experimental group since the
The effect of action learning on knowledge was measured. Students who attended the workshop(s) were random due to the volunteer nature of the workshops. Each student used his or her confidential pin number in lieu of putting his or her name on any of the questionnaires, pretests, or posttests. This pin number was documented on the consent form and collected by a research associate so as to differentiate participants used in the final analysis.

Students enrolled in all classes took the Visual (V), Aural (A), Read/Write (R), Kinesthetic (K) Questionnaire (VARK) at the beginning of the semester and a pretest and posttest for each of the four topics: 1) understanding and recognizing units of measure, 2) converting units of measure via dimensional analysis, 3) DNA structure, and 4) transcription and translation. Each pretest was given at the beginning of the semester prior to instruction on the topics, and the posttest were given the same day students took the exam covering those topics. For all students, pretests and posttests were given through Qualtrics, an online survey tool provided by The University of Southern Mississippi. Students were asked to print the completed survey screen which showed nothing but the proof of completion and turn in for credit as these were assignments integrated into the course. The pretests and posttests through Qualtrics, however, only included the pin number as an identifier. Students were asked to complete a printed copy of the VARK questionnaire with their pin number and return it to the instructor in a sealed envelope for credit, as this, too, was integrated as a course assignment.

There were four topics chosen from a General Biology I with lab course in which the workshops were offered. Those four topics included the following: recognizing units of measure, converting units of measure via dimensional analysis, DNA structure, and
transcription and translation. Each workshop was offered two times at the two campuses of the community college. For each topic, one of the workshops was an independent action learning workshop and the other was a cooperative action learning workshop. This meant that there were 16 workshops offered.

A one-way ANOVA statistical test was used to test the research hypotheses. The dependent variables included learning style and pretest and posttest scores. The independent variable was the workshop style: independent or cooperative. This study did not include controls for gender, age, or ethnicity.

Participants

The participants for this study were a nonrandom, convenience sample in that participants were chosen from the researcher’s classes as well as classes taught by the researcher’s colleagues; however, participants attending the workshops were random samples based on a students’ desire to attend a particular workshop or not. The instructors for the face-to-face courses at two different campuses of a southern community college were asked for permission to recruit participants from their courses for this study. The researcher requested that the face-to-face instructors read a script prepared by the researcher explaining the study and to recruit participants. The researcher also provided each student with a long consent form that fully explained the study. The instructors required all questionnaires, pretests, and posttests as a part of the requirements for the course. All participants were over the age of 18, so no parental consent was required.

The participants in this study were divided into two subsets: non-workshop students and workshop students. The control group was the non-workshop students. The
workshop students served as the experimental group since the effect that was measured is action learning workshops, independent or cooperative, on knowledge.

Instrumentation

In order to determine a student’s learning style to detect correlations among learning style and workshop style on knowledge, the VARK questionnaire was used (Appendix E). Neil Flemming approved the permission request to use the VARK questionnaire (Appendix F). The VARK questionnaire version 7.8 is composed of 16 multiple choice questions. Leite, Svinicki, and Shi (2010) provides reliability and validity for this instrument in using a four-factor CTCU model. The reliability estimates for VARK questionnaire scores are as follows: .85 visual, .82 aural, .84 read/write, and .77 kinesthetic, which is considered adequate (Leite et al., 2010).

Pretests and posttests were given for each of four topics: 1) recognizing units of measure, 2) converting units of measure via dimensional analysis, 3) DNA structure, and 4) transcription and translation. The pretests and posttests consisted of 10 multiple choice questions. These questions were validated by a panel of experts on the dissertation committee as well as instructors at the community college where the study was performed. The same questions were on the pretest and posttest for each topic in order to determine the students’ gain scores for each topic (Appendix G).

Procedure

Upon approval of MGCCC (Appendix B) and The University of Southern Mississippi’s IRB (Appendix A), participants were recruited from fourteen face-to-face General Biology I with lab courses at a southern community college during the fall 2015 semester. In order to recruit participants, the researcher provided a permission to recruit
students from specific courses (Appendix C), a participant consent letter (Appendix D), and an oral presentation during the first week of class. The oral presentation of the informed consent was given by the instructors to the classes. Students who chose to participate were able to drop out of the study without penalty at any time.

In order to maintain confidentiality, students identified themselves on all pretests, posttests, and questionnaires with a pin number they created. The students were asked to write their pin number on the consent form so that a record can be kept of the students’ pin number in case a student forgot. The consent forms were signed and kept by a research associate in a locked file cabinet. All assignments were required for the course as a completion grade; responses remained anonymous. While all students were required to participate in the questionnaire, pretest, and posttest for this study, they were not required to agree to be part of the study. Therefore, findings were only analyzed using data from students agreeing to be part of the study. In order to maintain anonymity, the students took all pretests and posttests through Qualtrics. For credit, they submitted a screen shot of each submission screen and uploaded it into an assignment link or printed the completion screen and turned it into the instructor for credit. The submission screens did not show any answers to questions, it simply showed that the assignment was completed. All results gathered through Qualtrics were password protected and only identified through the pin number for each student.

After consent was received, the VARK questionnaire and the Topic 1-4 pretests were administered to the students. The VARK questionnaire was given in order to determine the students’ learning style at the beginning of the semester and prior to any presentation of course material. The topic pretest was given as an indication of prior
knowledge while the topic posttests allowed for a detection of any knowledge gains after a topic was taught and/or workshop attended. Once the topic pretests had been given, the material was taught for Topic 1, followed by a workshop on Topic 1, followed by a posttest on Topic 1. This format was conducted for Topics 2-4 with posttests on each topic given the same day students took the in class exam covering that topic.

Upon receipt of consent, the VARK questionnaire and the Topics 1-4 pretests were administered to the students. Consent strictly allowed the inclusion of a participant’s data into the final analysis and did not include the actual participation in taking the questionnaire, pretests, or posttests as these were embedded in the course design. The VARK questionnaire was given at the beginning of the semester in order to determine a students’ learning style before the presentation of any course material. The topics pretests were also given at the beginning of the semester to indicate prior knowledge. Once the topic pretests had been given and the instructors had lectured on the topics, workshops were offered, followed by a posttest on Topic 1. Posttests for Topics 2 – 4 were given the same day students took the in-class exam covering that topic.

There were four different workshops offered throughout the fall 2015 semester on four different topics covered within a General Biology I with lab course: 1) understanding and recognizing units of measure, 2) converting units of measure via dimensional analysis, 3) DNA structure, and 4) transcription and translation. Each workshop was offered at least once as an independent action learning workshop and once as a cooperative action learning workshop at each of the two campuses, the workshop design is illustrated in Figure 3. The workshops, regardless of the style, were an hour in length and designed for students to engage in an activity exploring the particular topic.
presented. Students attending the independent action learning workshop style performed the activities independently from one another forcing students to think and act for oneself, eliminating any outside influence or control from other students. Students attending the cooperative action learning workshop style performed activities in groups, thereby allowing students to work together on completing the activity now exposing students to outside influences and control from others within the groups.

Figure 3. Workshop tree model summarizing the workshop layout and design.
Workshop 1 covered Topic 1, understanding and recognizing units of measure. In this workshop, regardless of style (independent vs. cooperative), students participated in a two-part activity (Appendix H) allowing them to explore the units of measure, both metric and English, as well as relationships among units of measure. The beginning of the workshop included a brief explanation of the activity to workshop attendees given by the workshop’s instructor. The activity also included a handout to guide students and require them to fill out questions outlined corresponding to the activity (Appendix H). The first part of the activity, part A, required students to first look at metric units of measure and arrange them in order from the smallest unit to the largest unit. Next students were given common objects and asked to place those objects next to the metric unit of measure that would most accurately measure that object according to its size. Students then took the English units of measure provided and placed them next to the objects already laid out according to the unit that would best measure that object. The second part of the activity, part B, required students to examine given objects without measuring them, estimate (guess) how long each object is by recording a guess in centimeters and a guess in inches. Once an estimate was recorded, the student(s) measured the object using a ruler in both centimeters and in inches. Once the student has both the estimate and actual measurement recorded, they then calculated their accuracy by using the following equation: Accuracy = \frac{|\text{Measured Value} - \text{Estimated Value}|}{\text{Measured Value}} \times 100.

Workshop 2 covered Topic 2, converting units of measure via dimensional analysis, regardless of style (independent vs. cooperative), students participated in an activity (Appendix H) allowing them to create pathways of moving from a known unit of
measure, one that is given, to an unknown unit of measure. The beginning of the workshop included a brief explanation of the activity to workshop attendees given by the workshop’s instructor. The activity included a handout to guide students and require them to fill out questions outlined corresponding to the activity (Appendix H). The activity provided students with a set of conversion cards, resembling dominos, which they arranged in a manner that would resemble dimensional analysis. Students needed to place the domino conversion cards so that the units of measure would cancel out thereby showing the problem solving process. Once students determined their pathway, they transferred the steps taken onto their handout.

Workshop 3 covered Topic 3, DNA structure, regardless of style (independent vs. cooperative), students participated in an activity (Appendix H) allowing them to explore the structure of a nucleotide (monomer) and the chemical process behind the formation of the polymer. The beginning of the workshop included a brief explanation of the activity to workshop attendees given by the workshop’s instructor. The activity included a handout to guide students and require them to fill out questions outlined corresponding to the activity (Appendix H). The activity required students to assemble a nucleotide, add nucleotides to form the polymer, and bond the nucleotides to the appropriate base pair complement.

Workshop 4 covered Topic 4, transcription and translation, regardless of style (independent vs. cooperative), students participated in an activity (Appendix H) allowing them to take a template strand of DNA through the process of transcription and translation used when making proteins. The beginning of the workshop included a brief explanation of the activity to workshop attendees given by the workshop’s instructor. The
activity included a handout to guide students and require them to fill out questions outlined corresponding to the activity (Appendix H). The activity required students to take a template strand of DNA through the process of transcription and translation.
CHAPTER IV – ANALYSIS OF DATA

The purpose of this study was to determine the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge of specified topics within a general biology course as well as attempt to determine whether there is a difference in students’ knowledge between the two different workshop styles. Whether there was a relationship between gain score and workshop style or a relationship between gain score and learning style was examined. Data were collected from students in fourteen face-to-face General Biology I with lab courses. The results of this study were used to determine whether workshop attendance, workshop style, and learning style effected students’ knowledge. The students who attended a workshop were treated as the experimental group, while the students that did not attend a workshop were treated as the control group.

Data for this study were collected from student answers on four topic pretests and posttests, the VARK questionnaire, and workshop sign in sheets. The topic pretests and posttests were used to determine student knowledge gain on specific topics. The VARK questionnaire was used to determine student learning styles of (a) visual, (b) aural, (c) read/write, and (d) kinesthetic. The workshop sign in sheets delineated the workshop style the student attended: (1) independent or (2) cooperative.

Data were quantitatively collected using SPSS (Version 23.0) to gather descriptives for participants in each of the instruments listed above, as well as several other statistical tests in order to answer all research questions. Descriptive data for gender, age, ethnicity, etc. were not collected and not presented in these findings. The
instruments used to collect data for this study included the VARK, Topics 1-4 pretests and posttests, and a workshop sign in sheet. Not all participants participated in every instrument. Table 1 shows the overall participation for this study in the control group (non-workshop), and Table 2 shows the overall participation for the experimental group (workshop).

Table 1

*Total Participation for Control Group*

<table>
<thead>
<tr>
<th>Instrument</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>VARK Questionnaire</td>
<td>286</td>
</tr>
<tr>
<td>Topic 1 Pretest + Posttest</td>
<td>115</td>
</tr>
<tr>
<td>Topic 2 Pretest + Posttest</td>
<td>84</td>
</tr>
<tr>
<td>Topic 3 Pretest + Posttest</td>
<td>47</td>
</tr>
<tr>
<td>Topic 4 Pretest + Posttest</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 2

*Total Participation for Experimental Group*

<table>
<thead>
<tr>
<th>Instrument</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>VARK Questionnaire</td>
<td>265</td>
</tr>
<tr>
<td>Topic 1 Pretest + Posttest</td>
<td></td>
</tr>
<tr>
<td>Independent Workshop</td>
<td>26</td>
</tr>
<tr>
<td>Cooperative Workshop</td>
<td>28</td>
</tr>
<tr>
<td>Topic 2 Pretest + Posttest</td>
<td></td>
</tr>
<tr>
<td>Independent Workshop</td>
<td>25</td>
</tr>
<tr>
<td>Cooperative Workshop</td>
<td>33</td>
</tr>
</tbody>
</table>
Table 2 (continued).

<table>
<thead>
<tr>
<th>Instrument</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 3 Pretest + Posttest</td>
<td></td>
</tr>
<tr>
<td>Independent Workshop</td>
<td>27</td>
</tr>
<tr>
<td>Cooperative Workshop</td>
<td>40</td>
</tr>
<tr>
<td>Topic 4 Pretest + Posttest</td>
<td></td>
</tr>
<tr>
<td>Independent Workshop</td>
<td>25</td>
</tr>
<tr>
<td>Cooperative Workshop</td>
<td>61</td>
</tr>
</tbody>
</table>

Table 3 includes basic descriptives for Topics 1-4. Descriptives for Topic 1 show that those who attended the cooperative action learning workshops had higher mean gain scores than those who attended the independent action learning workshops or attended no workshop. Descriptives for Topics 2-4 show that those who attended no workshop had higher mean gain scores than those who attended the cooperative action learning workshops or independent action learning workshops. Students who attended the independent action learning workshops for Topics 1, 3, and 4 had the lowest mean gain score.

Table 3

**Basic Descriptives for Topics 1-4.**

<table>
<thead>
<tr>
<th>Topic 1</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Workshop</td>
<td>.54</td>
<td>114</td>
<td>1.970</td>
</tr>
<tr>
<td>Independent Workshop</td>
<td>.50</td>
<td>28</td>
<td>2.009</td>
</tr>
<tr>
<td>Cooperative Workshop</td>
<td>.96</td>
<td>28</td>
<td>1.934</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 2</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Workshop</td>
<td>.92</td>
<td>84</td>
<td>2.330</td>
</tr>
<tr>
<td>Independent Workshop</td>
<td>.19</td>
<td>26</td>
<td>2.433</td>
</tr>
<tr>
<td>Cooperative Workshop</td>
<td>.06</td>
<td>34</td>
<td>2.558</td>
</tr>
</tbody>
</table>

Table 3 (continued).
Table 4 includes basic descriptives for learning styles when compared to each of the four topics. Descriptives for Topics 1, 3, and 4 show that students who were kinesthetic learners had higher mean gain scores than students who were either visual, aural, read/write, or those with multiple learning styles. Descriptives for Topic 2 show that students with an aural learning style had higher mean gain scores than students who were either visual, read/write, kinesthetic, or those with multiple learning styles.

Table 4

<table>
<thead>
<tr>
<th>Descriptives for Learning Styles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>Topic 1</td>
</tr>
<tr>
<td>Visual</td>
</tr>
<tr>
<td>Aural</td>
</tr>
<tr>
<td>Read/Write</td>
</tr>
<tr>
<td>Kinesthetic</td>
</tr>
<tr>
<td>Multi</td>
</tr>
</tbody>
</table>
Table 4 (continued).

<table>
<thead>
<tr>
<th>Topic 2</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>.67</td>
<td>6</td>
<td>2.658</td>
</tr>
<tr>
<td>Aural</td>
<td>2.33</td>
<td>6</td>
<td>3.011</td>
</tr>
<tr>
<td>Read/Write</td>
<td>-.11</td>
<td>9</td>
<td>2.472</td>
</tr>
<tr>
<td>Kinesthetic</td>
<td>-.07</td>
<td>30</td>
<td>2.406</td>
</tr>
<tr>
<td>Multi</td>
<td>-.89</td>
<td>9</td>
<td>1.764</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 3</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>.63</td>
<td>8</td>
<td>2.504</td>
</tr>
<tr>
<td>Aural</td>
<td>2.30</td>
<td>10</td>
<td>2.003</td>
</tr>
<tr>
<td>Read/Write</td>
<td>2.73</td>
<td>11</td>
<td>1.618</td>
</tr>
<tr>
<td>Kinesthetic</td>
<td>2.80</td>
<td>30</td>
<td>2.295</td>
</tr>
<tr>
<td>Multi</td>
<td>2.40</td>
<td>10</td>
<td>2.836</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topic 4</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td>2.27</td>
<td>15</td>
<td>1.792</td>
</tr>
<tr>
<td>Aural</td>
<td>2.38</td>
<td>13</td>
<td>2.399</td>
</tr>
<tr>
<td>Read/Write</td>
<td>1.64</td>
<td>11</td>
<td>1.286</td>
</tr>
<tr>
<td>Kinesthetic</td>
<td>2.46</td>
<td>37</td>
<td>2.387</td>
</tr>
<tr>
<td>Multi</td>
<td>1.58</td>
<td>12</td>
<td>2.678</td>
</tr>
</tbody>
</table>

Note. The mean possible score range for both the pretests and the posttests was 0 – 10, with 10 indicating a perfect score. For each individual learning style the score range was 0-16.

Findings

A one-way ANOVA was used to determine statistical significance for all three research questions. Table 5 shows that the variations of workshop styles was significant with respect to the gain score for Topics 1-4 and therefore accepts the assumption of equal variances.
Table 5

Levene’s Test for Homogeneity of Variance

<table>
<thead>
<tr>
<th>Variable</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1 Gain Score</td>
<td>2</td>
<td>.562</td>
<td>.571</td>
</tr>
<tr>
<td>Topic 2 Gain Score</td>
<td>2</td>
<td>.175</td>
<td>.840</td>
</tr>
<tr>
<td>Topic 3 Gain Score</td>
<td>2</td>
<td>.190</td>
<td>.827</td>
</tr>
<tr>
<td>Topic 4 Gain Score</td>
<td>2</td>
<td>.045</td>
<td>.956</td>
</tr>
</tbody>
</table>

* indicates a significant difference

Next, pretest and posttest gain scores were compared between workshop styles for each topic. Gain scores were calculated by subtracting the pretest score from the posttest score for each topic, and the mean gain score was determined for each topic. Table 6 shows the mean pretest, mean posttest, and mean gain score per topic.

Table 6

Mean Pretest, Mean Posttest, and Mean Gain Score per Topic

<table>
<thead>
<tr>
<th>Topic</th>
<th>N</th>
<th>Pretest Mean</th>
<th>SD</th>
<th>Posttest Mean</th>
<th>SD</th>
<th>Gain Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>ConRecUnit</td>
<td>114</td>
<td>6.41</td>
<td>1.87</td>
<td>6.96</td>
<td>1.78</td>
<td>.54</td>
</tr>
<tr>
<td>ExpRecUnit</td>
<td>56</td>
<td>6.53</td>
<td>1.67</td>
<td>7.18</td>
<td>1.56</td>
<td>.73</td>
</tr>
<tr>
<td>ConDimAnal</td>
<td>84</td>
<td>4.30</td>
<td>2.09</td>
<td>5.45</td>
<td>2.23</td>
<td>.92</td>
</tr>
<tr>
<td>ExpDimAnal</td>
<td>60</td>
<td>4.46</td>
<td>2.48</td>
<td>4.91</td>
<td>2.51</td>
<td>.12</td>
</tr>
<tr>
<td>ConDNAStr</td>
<td>46</td>
<td>3.24</td>
<td>1.68</td>
<td>6.02</td>
<td>2.06</td>
<td>3.09</td>
</tr>
<tr>
<td>ExpDNAStr</td>
<td>69</td>
<td>3.59</td>
<td>1.92</td>
<td>5.79</td>
<td>2.16</td>
<td>2.41</td>
</tr>
<tr>
<td>ConTransc/Transl</td>
<td>39</td>
<td>2.60</td>
<td>1.58</td>
<td>5.04</td>
<td>1.74</td>
<td>2.46</td>
</tr>
<tr>
<td>ExpTransc/Transl</td>
<td>88</td>
<td>2.95</td>
<td>1.69</td>
<td>5.06</td>
<td>1.95</td>
<td>2.19</td>
</tr>
</tbody>
</table>
Research Hypothesis One

Research hypothesis one stated that there will be a significant difference between the scores on the pre-workshop test and post-workshop test for each topic individually. A one-way ANOVA (Appendix I) was conducted for each topic comparing each topic gain score to the workshop style (non-workshop versus workshops). The one-way ANOVA for Topic 1 revealed a nonsignificant relationship between mean gain scores and workshop style, $F(2,167) = 0.576, p > .05$. The one-way ANOVA for Topic 2 revealed a nonsignificant relationship between mean gain scores and workshop style, $F(2,141) = 1.962, p > .05$. The one-way ANOVA for Topic 3 revealed a nonsignificant relationship between mean gain scores and workshop style, $F(2,112) = 1.707, p > .05$. The one-way ANOVA for Topic 4 revealed a nonsignificant relationship between mean gain scores and workshop style, $F(2,124) = 0.252, p > .05$. All four one-way ANOVAs revealed no significant difference between the mean gain scores of students who attended a workshop and students who did not attend a workshop.

Research Hypothesis Two

Research hypothesis two stated that there will be a significant difference when comparing pretest and posttest scores of those who attended the independent action learning workshop versus the pre-/post-test scores of those who attended the cooperative action learning workshop. Since the one-way ANOVAs that were conducted for each topic comparing each topic gain score to the workshop style (non-workshop versus workshops) revealed no significant difference, it also showed there was no significant difference detected for each topic gain score to the workshop style (independent verses cooperative).
Research Hypothesis Three

Research hypothesis three stated that there will be a significant difference in a students’ learning style, delineated from their VARK questionnaire scores, and the knowledge gained. A one-way ANOVA (Appendix J) was conducted for each topic comparing each topic gain score of the students to their learning style. The one-way ANOVA for Topic 1 revealed a nonsignificant relationship between mean gain scores and learning style, $F (4,51) = 0.077, p > .05$. The one-way ANOVA for Topic 2 revealed a nonsignificant relationship between mean gain scores and learning style, $F (4,55) = 1.786, p > .05$. The one-way ANOVA for Topic 3 revealed a nonsignificant relationship between mean gain scores and learning style, $F (4,64) = 1.510, p > .05$. The one-way ANOVA for Topic 4 revealed a nonsignificant relationship between mean gain scores and learning style, $F (4,83) = 0.553, p > .05$. All four one-way ANOVAs revealed no significant difference between the mean gain scores of students and learning styles.

Although non-significance was found among the learning styles and knowledge gain, a comparison of the mean gain scores and the individualized learning styles revealed some interesting findings (Figures 4-7). First, certain learning styles appear to have larger gain scores with certain topics. For Topic 1 (Figure 4), students with visual, kinesthetic, or multiple learning styles appear to have a greater knowledge gains than individuals with aural, read/write learning styles.
Figure 4. Comparison of mean test scores from Topic 1 and learning styles for control and experimental groups.

The vertical axis represents the mean gain score calculated from the difference in pretest and posttest scores while the horizontal axis represents each learning style category delineated by the VARK questionnaire.

For Topic 2 (Figure 5), students with visual and aural learning styles appear to have a greater knowledge gains than individuals with read/write, kinesthetic, or multiple learning styles.
Figure 5. Comparison of mean test scores from Topic 2 and learning styles for control and experimental groups.

The vertical axis represents the mean gain score calculated from the difference in pretest and posttest scores while the horizontal axis represents each learning style category delineated by the VARK questionnaire.

For Topic 3 (Figure 6), students’ knowledge gains among learning styles appears large among the various learning style categories.

Figure 6. Comparison of mean test scores from Topic 3 and learning styles for control and experimental groups.

The vertical axis represents the mean gain score calculated from the difference in pretest and posttest scores while the horizontal axis represents each learning style category delineated by the VARK questionnaire.

For Topic 4 (Figure 7), students’ knowledge gains appears to be large and almost equal among the various learning style categories.
Figure 7. Comparison of mean test scores from Topic 4 and learning styles for control and experimental groups.

The vertical axis represents the mean gain score calculated from the difference in pretest and posttest scores while the horizontal axis represents each learning style category delineated by the VARK questionnaire.

Secondly, certain topics appear to have more knowledge gains than other topics covered, regardless of the learning style or attendance of a workshop. For Topics 3 and 4 (Figures 6 and 7 respectively), students’ knowledge gains appears to be larger overall than for Topics 1 and 2 (Figures 4 and 5 respectively).

Summary

This study contained three research questions directed towards understanding the relationship between students’ knowledge gain and workshop style for four topics in face-to-face General Biology I with lab courses offered at a southern community college. The research questions were analyzed by one-way ANOVAs. The findings of this study indicated the presence of a workshop in addition to lecture did not significantly impact students’ knowledge on each of the four chosen topics. Also, no significance was found between students’ learning style(s) and knowledge gains.
CHAPTER V - DISCUSSION

This chapter includes a summary of this study along with a discussion of the results. Limitations regarding the study will be discussed as well as recommendations for future research. Conclusions drawn from the results of this study will also be discussed with regard to considerations of action learning workshop implementation.

Summary of the Study

This study focused on determining the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge of specified topics within a General Biology I with lab course. This study also attempted to determine whether there was a difference in students’ knowledge between the two different workshop styles. The study investigated whether students’ knowledge on four topics improved following a supplemental process workshop involving active learning. Random assortment of students into control and experimental groups occurred throughout the study as workshop attendance was voluntary. The study was quantitatively analyzed based on VARK questionnaires, workshop attendance, and pretest/posttest design to determine differences in gain scores for control and experimental groups.

A one-way ANOVA (Appendix I) was conducted during this study for each of the four topics to compare differences in gain scores of students who participated in a workshop and those that did not. Also, a one-way ANOVA (Appendix J) was conducted for each of the four topics to compare differences in gain scores of students and their learning styles.
Description of Sample Participants

The participants of this study were chosen based solely on their enrollment in the fourteen face-to-face General Biology I with lab courses offered at a southern community college. Demographics such as age, race, ethnicity, prior knowledge or experience, nor any other factors about the students were used to determine whether a participant was asked to be a part of this study. There were a total of 336 participants; however, not all of them participated in every aspect of the study.

Description of Study Variables

The variables in this study consisted of the VARK questionnaire, topic pretests/posttests, and workshop sign in sheets. The VARK questionnaire was used in order to determine a student’s learning style to detect correlations among learning style and workshop style on knowledge (Appendix E). Pretests and posttests (Appendix G), consisting of ten questions, for each topic were used to determine students’ knowledge gain. Workshop sign in sheets were used to keep track of workshop attendance. The activities used in the workshops required active learning by requiring students to complete a task via a manipulative.

Analysis of Research Questions and Hypotheses

Research Question One

How does students’ knowledge change following an action learning workshop?

It was hypothesized that there would be a significant difference between the scores on the pretest and posttest of those who did not attend a workshop versus those who did attend a workshop. The hypothesis above was tested for each workshop offered on Topics 1-4. Statistical analysis revealed that this hypothesis was not supported by the
findings of this study as no significant difference was found between the gain scores of those who attended a workshop and those who did not attend a workshop. These findings suggest that students who attended a workshop did not gain more knowledge of the topic than students who did not attend a workshop. There was no significant difference in students’ performance after an action learning workshop.

This study contradicts various studies (Douglas & Machin, 2004; Drane et al., 2005; Duncan & Dick, 2000) that have provided support for workshop program success within sciences. Perhaps this contradiction suggests that simply implementing workshop programs is not enough to support knowledge gain, but rather workshop design is a key component to a workshop’s success. Though each workshop was instructor-facilitated, the instructor’s role in guiding students through the activity was minimal and rather hands-off. Perhaps this reflects a necessity for more of an instructor-led approach in which the instructor guides the students through the activity, thereby provoking specific important lines of inquiry required for knowledge gain on a specific topic.

*Research Question Two*

Was there a difference in students’ knowledge between the independent action learning and the cooperative action learning workshop?

It was hypothesized that there would be a significant difference when comparing pretest and posttest scores of those who attended the independent action learning workshop versus the pre-/post-test scores of those who attended the cooperative action learning workshop. The hypothesis above was tested for each workshop offered on Topics 1-4. Statistical analysis revealed that this hypothesis was not supported by the findings of this study as no significant difference was found between the gain scores of
those who attended an independent action learning workshop and those who attended a
cooperaive action learning workshop. These findings suggest that the workshop style
(independent or cooperative) did not have a significant impact in students’ knowledge
 gain on a topic. There was no significant difference in students’ performance after an
independent action learning workshop or a cooperative action learning workshop.

Since there was no significance found among the two workshop styles and
knowledge gain, this study contradicts the significance of independent action learning
and Franks and Jewitt (2001) support the importance of action learning on students’
knowledge gain, perhaps the action (e.g. activity and/or manipulative) implemented is not
as significant, but rather the mode to which the action is implemented is important. It is
not enough to simply implement an action learning workshop centered on a specific task,
but in fact the guidance through completing the task that is key to the success of the
action on increasing students’ knowledge.

Research Question Three

Does students’ learning styles affect the knowledge gained?

It was hypothesized that there would be a significant difference in a students’
learning style, delineated from their VARK questionnaire scores, and knowledge gained.
The hypothesis above was tested for each workshop offered on Topics 1-4. These
findings suggest that the students’ learning style did not have a significant impact in
students’ knowledge gain on a topic.

Though research has resulted in the advantages of VARK methods in areas of
chemistry and physics on reinforcing content while engaging students in inquiry,
exploration, and collaboration, the results of this study revealed no advantage of VARK methods and the amount of knowledge gained on a particular topic. Perhaps this reflects the necessity for implementing an instructor-led mode of guided discovery through which each learning style is addressed as the activity progresses.

**Implications of Policy and Practice**

The results of this study could impact implementation practices of workshop programs as supplemental instruction in the biological sciences. The outcomes of this study indicate that the implementation of an action learning workshop program is not important to students’ knowledge gain on specific topics within the biological sciences. Though this study contradicts outcomes of previous studies (Duncan & Dick, 2000; Fullilove & Treisman, 1990; Hanson & Wolfskill, 2000; Udovic et al., 2002), it could offer insights into the importance of implementation practices, instructor involvement, and action design.

This study’s findings suggest that clear consideration should be taken when implementing a process workshop. Implementing an action-learning workshop requires detailed attention with respect to instructor involvement and student demands during the activity. Students within the sciences often struggle with concepts when there is minimal guidance from an instructor thereby propagating confusion and frustration (Brown & Campione, 1994; Hardimann, Pollatsak, & Weil, 1986).

Though there is evidence that action-based learning can be effective within the sciences it is important to consider the instructors role. Michael (2006) states the importance of reforming current teaching practices to implement action learning, but this is predicated on the instructor playing an active role in guiding students through action-
based learning processes. Although this study revealed no significant difference in the knowledge gain outcomes of those who attended an independent action learning workshop or a cooperative action learning workshop, it does suggest the importance of a more hands-on instructor support. Though cooperative learning provides a social environment for inquiry, the mode of inquiry that took place within this study did not yield more knowledge gain, therefore suggesting modes of thinking within the groups were no different from the individuals in the independent action learning environment. This study provides support emphasizing an instructor-led guided active learning workshop, whereby students are actively learning, but have an instructor asking specific questions during specific points of time throughout the activity to provoke conceptual understanding of topics (Brown, 2010; Drake, 2011; Shaya et al., 1993; Udovic et al., 2002).

Limitations

The participants within this study were limited to fourteen face-to-face General Biology I with lab students at a southern community college during the fall 2015 semester, so these results may not be able to be generalized beyond this sample. The students represented various majors, and were not distributed equally by age, gender, nor ethnicity; therefore, demographics may have affected the results of this study; however, that data was not examined. The results of this study were limited to the students’ effort during the fall 2015 semester to complete the VARK questionnaire, all pretests, posttests, and workshop attendance. Because these instruments were not graded for accuracy, nor proctored, further limitations include honesty and accuracy. Students may have answered questions carelessly, referred to notes or other resources when instructed not to do so, or
rushed through the assignments. Instructors for the courses were not constant as the participants were selected from several General Biology I with lab courses from different campuses of the institution; therefore, students may have been paced differently as to when the lecture was given for a particular topic or exposed to different teaching methodologies. Several instructors conducted the workshops; therefore, results may reflect the type of guidance provided during facilitation of the workshops themselves. Finally, all pretests were given at the beginning of the semester while each posttest was given the day students took the in class exam covering that particular topic.

Reccomendations for Future Research

While implementation of action learning and workshop programs as supplemental instruction are on the rise, it is apparent that careful consideration and unique individualized thought is important when implementing such programs if increased students’ knowledge is to be expected. This study provides promising insight into potential considerations that should be shown when action learning workshops are to become effective toward knowledge gains on specific topics covered in general biology courses.

The first recommendation is to conduct this study that is more reflective of the overall topics covered in General Biology I with lab courses as this study focused on a narrow range of topics. Also, conducting this study over a longer period of time in order to include a more robust representation of student population at the southern community college would be ideal.

The second recommendation is to conduct the pretests and posttests in a proctored setting in order to retain a more accurate representation of students’ knowledge gain as
they may feel it is more important to answer questions as accurately as possible. This would provide a better outlook on the actual knowledge gained by each individual student between the groups.

The third recommendation is to conduct qualitative analysis on the participants of this study. Quantitative analysis sometimes neglects certain aspects that would explore insight regarding the results. This would provide a better understanding of the importance of instructor-led modes of inquiry and cooperative interactions among peers.

A fourth recommendation is to conduct qualitative analysis on the course instructors and the workshop instructors of this study. This would provide a better understanding of lecture design and teaching methodologies used by the course instructors that may have impacted the quantitative results. Also, insight into how facilitation occurred throughout the workshops may explain any impacts instructor guidance, or lack thereof, may have had on the quantitative results.

A final recommendation would be to perform a study that investigates the depth to which instructor guidance is required for students’ knowledge gain through action learning. This may help to better understand the importance of an instructor’s role with respect guided discovery within self-directed learning and cooperative learning environments.

The purpose of this study was to determine the effects of cooperative learning workshops and independent action learning workshops on students’ knowledge of specific topics within a General Biology I with lab course, as well as attempt to determine whether there was a significant difference in students’ knowledge between the two different workshop styles. Further research on this topic is important because so little
exists on combining these aspects in workshop design, especially for general biology courses that are key to having a solid foundation for further academic progression. While the knowledge outcomes between workshop groups and learning styles were not significantly different, these findings, with those of future studies, may lead to implementation of an effective workshop program that enhances learning quality and thereby increases students’ knowledge. Also, suggestions presented in this study may benefit community college students, instructors, and administrators and help ensure quality education.
APPENDIX A – IRB Approval Letter

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS  39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

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

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the “Adverse Effect Report Form”.
- If approved, the maximum period of approval is limited to twelve months. Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 15050601
PROJECT TITLE: Supplemental Action Learning Workshops: Understanding the Effects of Independent and Cooperative Workshops on Students’ Knowledge
PROJECT TYPE: New Project
RESEARCHER(S): Kathryn Morris
COLLEGE/DIVISION: College of Science and Technology
DEPARTMENT: Center for Science and Math Education
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF APPROVAL: 06/03/2015 to 06/02/2016

Lawrence A. Hosman, Ph.D.
Institutional Review Board
APPENDIX B – Permission to Conduct Research at
Mississippi Gulf Coast Community College

### Request to Conduct Research at MGCCC

**DIRECTIONS:** Individuals who wish to conduct research utilizing MGCCC students or employees must complete this application and email to jason.pugh@mgccc.edu.

**Purpose:** This application must be completed and approval granted by the MGCCC Executive Council prior to conducting any research utilizing college students or employees. The purpose of this application is to ensure that the researcher complies with the following conditions:

1. Requires the researcher to summarize the proposed research and provide supporting documentation ensuring that research is performed in compliance with all applicable laws, regulations, and institutional and federal policies regarding human subjects research,
2. Ensures the proposed research has institutional support or will have such support through IRB approval and the endorsement of a qualified research advisor (i.e., faculty member) who assumes responsibility for the project,
3. Provides the applicant with appropriate documentation that the MGCCC Executive Council has reviewed the proposed study.

**Principal Investigator (PI) Contact Information:** The PI for the purposes of this application is an individual who will personally conduct this research study. Under most circumstances, the PI will be the student researcher.

<table>
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<tr>
<th>Name</th>
<th>Kathryn Morris</th>
<th>Phone:</th>
<th>(228) 497-7595</th>
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<tbody>
<tr>
<td>Email</td>
<td><a href="mailto:Kathryn.morris@mgccc.edu">Kathryn.morris@mgccc.edu</a></td>
<td>Fax:</td>
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<tr>
<td>Address</td>
<td>2300 Highway 90</td>
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**Research Advisor (RA) Contact Information:** The RA for the purposes of this application is an individual who will personally supervise and oversee this research study. Under most circumstances, the RA will be the faculty member working with the student researcher.

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<thead>
<tr>
<th>Name</th>
<th>Dr. Sherry Herron</th>
<th>Phone:</th>
<th>(601) 266-5087</th>
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<tr>
<td>Email</td>
<td><a href="mailto:Sherry.herron@usm.edu">Sherry.herron@usm.edu</a></td>
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<tr>
<td>Address</td>
<td>538 College Drive #5087</td>
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**Sponsoring Institution or Agency:**

**Sponsoring Academic Division/Department:**

- **Has the study obtained IRB approval from sponsoring institution?**
  - [ ] Yes, Approve Date ____________ If Yes, was Study [ ] Exempt or Expedited (deemed minimal risk to human subjects)
  - [ ] No
  - [x] Not Applicable, Explain:
    - [ ] Full Board (deemed greater than minimal risk or work with special populations of human subjects)

**IRB approval from the University of Southern Mississippi is pending permission from MGCCC to use students as participants.**
APPENDIX C – Permission from Instructors to Recruit Students and to Include Study Components as Course Requirements

Mary S. Graham, President
www.mgcc.edu

MGCCC
Mississippi Gulf Coast Community College
“Making a positive difference...”

March 5, 2015,

Permission to Recruit Students

Upon IRB approval of “Supplemental Action Learning Workshops: Understanding the effects of independent and cooperative workshops on students’ knowledge,” I give permission to recruit students from my BIO 1134 courses. I understand that the agreement or disagreement of my students to participate and the analysis of data collected throughout this course are completely voluntary. I am also aware that I will not be informed of specific responses from students participating in the study.

I understand that I can withdraw my permission to observe my course at any time throughout the project without reprocussions.

Sincerely,
APPENDIX D – Oral Presentation and Informed Consent Letter

THE UNIVERSITY OF SOUTHERN MISSISSIPPI AUTHORIZATION TO PARTICIPATE IN RESEARCH PROJECT

Consent is hereby given to participate in the study entitled:
Supplemental Action Learning Workshops: Understanding the Effects of Independent and Cooperative Workshops on Students’ Knowledge

Purpose: The purpose of this study is to determine the effects of cooperative action learning workshops and independent action learning workshops on students’ knowledge of specified topics within a general biology course. This study will also attempt to determine whether there is a difference in students’ knowledge between the two different workshop styles.

Implications of this study include the ability to design supplemental instruction through the implementation of effective workshops in order to improve students’ knowledge of scientific topics and dissemination of that knowledge. This would, in turn, improve student academic confidence thereby increasing the likelihood of completing degree programs. Community colleges were chosen for this study because of open enrollment policies bringing in two distinct groups of students. For example, many students have varying extracurricular stressors demanding attention be diverted from coursework. Though workshops as supplemental instruction have proven beneficial in increasing students’ knowledge among the sciences, research is lacking on workshops as teaching aids on specific topics covered in general biology with regards to effective styles when applying action learning, so this study may improve upon the small amount of findings available to this date.

Description of Study: Quantitative data will be gathered through the use of specifically designed topic pretests, posttests, and questionnaires. The VARK questionnaire will be given to the student to determine individual learning style. All pretests and posttests will be given through a survey website, but the link to each will be posted in Canvas.

The students chosen for this research study include students from face-to-face biology courses at a southern community college.

Benefits: The students will gain a better insight into their individual learning style; thereby, giving them a sense of activities best suited for their learning style. Data collected during this project may also lead to the development and implementation of more effective workshop series to supplement instruction. The development of action learning workshops will thereby enhance the educational experience providing enjoyable hands-on activities to help grasp difficult content and/or concepts yielding an increase in students’ academic confidence and performance.
The students will receive entrance into a drawing for one of two $50 Visa gift cards awarded at the close of the study.

**Risks:** There are no risks associated with this study outside of risks associated with normal daily life activities.

**Confidentiality:** All student responses and correspondence will be identified only through a 4-digit pin chosen by the student and unknown by the researcher or instructor of the course. Physical data sources, such as consent forms and VARK questionnaires, will be destroyed after the conclusion of this study. Before conclusion of the study, physical data sources will be kept in a locked file cabinet or password-locked digital files by a research associate. For the analysis and reporting of findings, pseudonyms will be used in order to protect the identities of the participants.

**Alternative Procedure:** There are no alternative procedures for this study.

**Participant’s Assurance:** Whereas no assurance can be made concerning the results that may be obtained (since results from investigational studies cannot be predicted) the researcher will take every precaution consistent with the best scientific practice. Participation in this project is completely voluntary, and participants may withdraw from this study at any time without penalty or prejudice. Questions concerning the research should be directed to Kathryn Morris at 228-497-7695. This project and this consent form have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5116, Hattiesburg, MS 39406-0001, (601) 266-5997. A copy of this form will be given to the participant.

**VERY IMPORTANT:**

**Signatures:** In conformance with the federal guidelines, the signature of the participant must appear on all written consent documents. The University also requires that the date and the signature of the person explaining the study to the subject appear on the consent form.

☐ I, the consenting participant, am at least 18 years of age. Remember, your data is anonymous to the researcher and instructor, and there are no requirements for the study other than course assignments already required for course credit.

☐ I DO NOT consent to the use of my data in the final analysis for this research project.

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<th>Signature of the Research Participant</th>
<th>4-digit pin</th>
<th>Date</th>
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62
4-DIGIT PIN – PLEASE CHOOSE A NUMBER YOU WILL REMEMBER BECAUSE THIS IS WHAT YOU WILL USE TO SIGN INTO EACH SURVEY, PRETEST, OR POSTTEST.

COURSE SECTION (PLEASE INCLUDE COURSE SECTION AND INSTRUCTOR NAME – THE SECTION SHOULD BE ABLE TO BE FOUND ON CANVAS)

________________________________________________________________________________________________________________________________________________________

Signature of the Person Explaining the Study                                      Date

*** To submit this form, sign and scan it and email to rachel.ryan@mgccc.edu or take a picture of it and email it to the same email address. If you forget your 4-digit pin, please also email her to retrieve the pin. IT IS IMPORTANT TO USE THE SAME PIN FOR EACH ACTIVITY!
THANK YOU TRULY FOR YOUR PARTICIPATION!
APPENDIX E – Visual, Aural, Read/Write, Kinesthetic (VARK) Questionnaire

The VARK Questionnaire (Version 7.8)

How Do I Learn Best?

Choose the answer which best explains your preference and circle the letter(s) next to it.

Please circle more than one if a single answer does not match your perception.

Leave blank any question that does not apply.

1. You are helping someone who wants to go to your airport, the center of town or railway station. You would:
   a. go with her.
   b. tell her the directions.
   c. write down the directions.
   d. draw, or show her a map, or give her a map.

2. A website has a video showing how to make a special graph. There is a person speaking, some lists and words describing what to do and some diagrams. You would learn most from:
   a. seeing the diagrams.
   b. listening.
   c. reading the words.
   d. watching the actions.

3. You are planning a vacation for a group. You want some feedback from them about the plan. You would:
   a. describe some of the highlights they will experience.
   b. use a map to show them the places.
   c. give them a copy of the printed itinerary.
   d. phone, text or email them.

4. You are going to cook something as a special treat. You would:
   a. cook something you know without the need for instructions.
   b. ask friends for suggestions.
   c. look on the Internet or in some cookbooks for ideas from the pictures.
   d. use a good recipe.

5. A group of tourists want to learn about the parks or wildlife reserves in your area. You would:
   a. talk about, or arrange a talk for them about parks or wildlife reserves.
   b. show them maps and internet pictures.
   c. take them to a park or wildlife reserve and walk with them.
   d. give them a book or pamphlets about the parks or wildlife reserves.

6. You are about to purchase a digital camera or mobile phone. Other than price, what would most influence your decision?
   a. Trying or testing it.
   b. Reading the details or checking its features online.
   c. It is a modern design and looks good.
   d. The salesperson telling me about its features.

7. Remember a time when you learned how to do something new. Avoid choosing a physical skill, e.g., riding a bike. You learned best by:
   a. watching a demonstration.
   b. listening to somebody explaining it and asking questions.
   c. diagrams, maps, and charts - visual cues.
   d. written instructions – e.g., a manual or book.
8. You have a problem with your heart. You would prefer that the doctor:
   a. gave you something to read to explain what was wrong.
   b. used a plastic model to show what was wrong.
   c. described what was wrong.
   d. showed you a diagram of what was wrong.

9. You want to learn a new program, skill or game on a computer. You would:
   a. read the written instructions that came with the program.
   b. talk with people who know about the program.
   c. use the controls or keyboard.
   d. follow the diagrams in the book that came with it.

10. I like websites that have:
    a. things I can click on, shift or try.
    b. interesting design and visual features.
    c. interesting written descriptions, lists and explanations.
    d. audio channels where I can hear music, radio programs or interviews.

11. Other than price, what would most influence your decision to buy a new non-fiction book?
    a. The way it looks is appealing.
    b. Quickly reading parts of it.
    c. A friend talks about it and recommends it.
    d. It has real-life stories, experiences and examples.

12. You are using a book, CD or website to learn how to take photos with your new digital camera. You would like to have:
    a. a chance to ask questions and talk about the camera and its features.
    b. clear written instructions with lists and bullet points about what to do.
    c. diagrams showing the camera and what each part does.
    d. many examples of good and poor photos and how to improve them.

13. Do you prefer a teacher or a presenter who uses:
    a. demonstrations, models or practical sessions.
    b. question and answer, talk, group discussion, or guest speakers.
    c. handouts, books, or readings.
    d. diagrams, charts or graphs.

14. You have finished a competition or test and would like some feedback. You would like to have feedback:
    a. using examples from what you have done.
    b. using a written description of your results.
    c. from somebody who talks it through with you.
    d. using graphs showing what you had achieved.

15. You are going to choose food at a restaurant or cafe. You would:
    a. choose something that you have had there before.
    b. listen to the waiter or ask friends to recommend choices.
    c. choose from the descriptions in the menu.
    d. look at what others are eating or look at pictures of each dish.

16. You have to make an important speech at a conference or special occasion. You would:
    a. make diagrams or get graphs to help explain things.
    b. write a few key words and practice saying your speech over and over.
    c. write out your speech and learn from reading it over several times.
    d. gather many examples and stories to make the talk real and practical.
The VARK Questionnaire Scoring Chart

Use the following scoring chart to find the VARK category that each of your answers corresponds to. Circle the letters that correspond to your answers.

**e.g.** If you answered b and c for question 3, circle V and R in the question 3 row.

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**Scoring Chart**

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<tr>
<td>10</td>
<td>$K$</td>
<td>$V$</td>
<td>$R$</td>
<td>$A$</td>
</tr>
<tr>
<td>11</td>
<td>$V$</td>
<td>$R$</td>
<td>$A$</td>
<td>$K$</td>
</tr>
<tr>
<td>12</td>
<td>$A$</td>
<td>$R$</td>
<td>$V$</td>
<td>$K$</td>
</tr>
<tr>
<td>13</td>
<td>$K$</td>
<td>$A$</td>
<td>$R$</td>
<td>$V$</td>
</tr>
<tr>
<td>14</td>
<td>$K$</td>
<td>$R$</td>
<td>$A$</td>
<td>$V$</td>
</tr>
<tr>
<td>15</td>
<td>$K$</td>
<td>$A$</td>
<td>$R$</td>
<td>$V$</td>
</tr>
<tr>
<td>16</td>
<td>$V$</td>
<td>$A$</td>
<td>$R$</td>
<td>$K$</td>
</tr>
</tbody>
</table>

**Calculating your scores**

Count the number of each of the VARK letters you have circled to get your score for each VARK category.

- Total number of $\text{V}$s circled = 
- Total number of $\text{A}$s circled = 
- Total number of $\text{R}$s circled = 
- Total number of $\text{K}$s circled = 

66
APPENDIX F – Permission to use the VARK Questionnaire

From: Fleming Neil <flemingn@ihug.co.nz>
Sent: Thursday, August 21, 2014 8:38 PM
To: Morris, Kathryn
Subject: Using VARK

Dear Kathryn,

Thank you for seeking permission to use VARK™. We welcome VARK users and we appreciate the honesty of people to act in a professional way when using our copyright and trademarked materials. From our beginnings we wanted VARK to be free for use by teachers and students in universities, colleges and high schools. To achieve that we needed to charge fees for those who use VARK as part of their profit or not-for-profit business.

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Also available is a VARK Profile that provides helpful advice for effective study strategies using your preferences. That can be purchased immediately after completing the VARK questionnaire online but leave your computer running as it will come as a download. If you are using VARK™ for research, please note that we have two scoring systems and one is designed specifically for research. The information about each system is at these web addresses:


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APPENDIX G – Pretests/Posttests

Topic 1: Understanding and Recognizing Units of Measure

Instructions: Please choose the answer that best fits each question. These answers will not count against your grade.

1. Measure the length of the pencil in centimeters to the nearest tenth.

   ![Image of a ruler measuring a pencil length]
   a. 18.5 cm
   b. 19.0 cm
   c. 18.0 cm
   d. 18.3 cm
   e. 18.7 cm

2. Which of the following has units of measure in order from smallest to the largest?
   a. kilometer, meter, centimeter, millimeter
   b. millimeter, centimeter, meter, kilometer
   c. meter, kilometer, centimeter, millimeter
   d. millimeter, kilometer, meter, centimeter
   e. centimeter, millimeter, meter, kilometer

3. The standard SI unit form measuring volume is the ____.
   a. meter
   b. liter
   c. gram
   d. gram/cm³
   e. seconds

4. To convert a larger SI unit to a smaller SI unit, the decimal point should be moved to the _____.
   a. right
   b. left
5. Which of the following most closely represents the length of 1 meter?
   a. length of a football field
   b. length of a bus
   c. height of a doorknob
   d. width of your hand

6. One gallon is equal to how many quarts?
   a. 2
   b. 4
   c. 6
   d. 8
   e. 16

7. Which prefix means one-tenth?
   a. hecto
   b. decka
   c. deci
   d. centi
   e. milli

8. 1000 meters is a
   a. millimeter
   b. hectometer
   c. kilometer
   d. centimeter
   e. megameter

9. A mile is the same as
   a. 1,560 yards
   b. 5,280 feet
   c. 53,360 inches

10. Which of these is a measure of distance?
    a. acre
    b. pint
    c. yard
    d. pound
Topic 2: Converting Units of Measure via Dimensional Analysis

Instructions: Please choose the answer that best fits each question. These answers will not count against your grade.

1. Which of the following is/are true of the following unit conversion shown below?

\[
\frac{10.0 \text{ inches}}{1} \times \frac{2.54 \text{ cm}}{1 \text{ inch}} \times \frac{1 \text{ meter}}{100 \text{ cm}} = \]

a. 100 cm = 1 meter  
b. the numerical answer is 0.254 cm  
c. all the units cancel out except for meters  
d. all of the above  
e. none of the above

2. A mass of 0.15 ounces is equal to how many grams?
   a. 0.2352 g  
b. 0.24 g  
c. 4.25 g  
d. 4.3 g  
e. none of the above are correct

3. 2.00 gallons is equal to how many liters?
   a. 0.1321 L  
b. 0.528 L  
c. 7.57 L  
d. 8.45 L  
e. 8.5 L

4. What is the mass, in grams, of a 16.0 lb bowling ball?
   a. 7300 g  
b. 0.0352 g  
c. 7260 g  
d. 6520 g  
e. 8000 g

5. A beaker contains 578 mL of water. What is the volume in quarts?
   a. 0.578 qt  
b. 0.611 qt  
c. 0.153 qt  
d. 1.22 qt  
e. 4 qts
6. What is the volume of a half-gallon carton of milk in milliliters?
   a. 1916 mL
   b. 500 mL
   c. 1561 mL
   d. 1893 mL
   e. 2000 mL

7. The mileage rating of an automobile that is 12.0 kilometers per liter could also be expressed as ________ miles per gallon.
   a. 28.2
   b. 31.6
   c. 32.0
   d. 32.6
   e. 73.1

8. The average American student is in class 330 minutes/day. How many hours/day is this?
   a. 5.5 hr/day
   b. 19,800 hr/day
   c. 0.092 hr/day
   d. 1,188,000 hr/day

9. A family pool holds 10,000 gallons of water. How many cubic meters is this?
   a. 37,854 m$^3$
   b. 37.85 m$^3$
   c. 378,500 m$^3$
   d. 37,850,000 m$^3$
   e. there is no way to convert from the given unit to cubic meters

10. Blood sugar levels are measured in milligrams of glucose per deciliter of blood volume. If a person’s blood sugar level measured 128 mg/dL, how much is this in grams per liter?
    a. 1.28 g/L
    b. 12,800 g/L
    c. 0.0128 g/L
    d. 1,280 g/L
Topic 3: DNA Structure

Instructions: Please choose the answer that best fits each question. These answers will not count against your grade.

1. DNA is made up of how many strands?
   a. 1
   b. 2
   c. 4
   d. 6
   e. 12

2. The building blocks of nucleic acids are
   a. amino acids
   b. nucleotides
   c. pentose sugars
   d. phosphate groups
   e. nitrogenous bases

3. DNA contains all of the following nitrogen bases EXCEPT
   a. adenine
   b. thymine
   c. guanine
   d. uracil
   e. cytosine

4. Each DNA strand that consists of alternating
   a. covalent and ionic bonds
   b. nitrogen containing bases
   c. sugar and phosphate molecules
   d. hydrogen bonds
   e. covalent and hydrogen bonds

5. Which of the following statements is TRUE?
   a. The hydrogen bonding of cytosine to guanine is an example of complementary base pairing.
   b. In DNA, adenine always base pairs with guanine, and cytosine always base pairs with thymine.
   c. Each of the four nucleotides in a DNA molecule has the same nitrogen-containing base.
   d. When adenine base pairs with thymine, they are linked by three hydrogen bonds.
   e. All of these statements are true
6. The two polynucleotide chains in DNA are
   a. semidiscontinuous
   b. semiconservative
   c. parallel
   d. discontinuous
   e. antiparallel

7. When comparing DNA structure to a ladder, the “rung” of the ladder are
   a. sugar
   b. phosphate
   c. paired nitrogenous bases
   d. joined sugars and phosphates
   e. all of the above

8. A nucleotide consists of
   a. a phosphate and a base
   b. a phosphate and a sugar
   c. a base and an amino acid
   d. a phosphate and an amino acid
   e. a phosphate, a sugar, and a nitrogen base

9. The sugar in DNA is
   a. glucose
   b. ribose
   c. deoxyribose
   d. pentose
   e. none of the above

10. A major characteristic of the structure of DNA is that
    a. the ratio of A to C is close to 1:1 and the ratio of G to T is close to 1:1
    b. the ratio of A to T is close to 1:1 and the ratio of G to C is close to 1:1
    c. the ratio of A to G is close to 1:1 and the ratio of T to C is 1:1
    d. A + T = G + C
    e. A + G = C + T
Topic 4: Transcription/Translation

Instructions: Please choose the answer that best fits each question. These answers will not count against your grade.

1. Select the INCORRECT statement about transcription.
   a. DNA is used as a template to make RNA.
   b. DNA is made as a complementary strand to DNA.
   c. Gene expression begins with this process.
   d. Ribonucleoside triphosphates pair with exposed bases.

2. For translation the start codon is often _{(1)}_, which codes for _{(2)}_.
   a. 1-ATG, 2-histidine
   b. 1-GTA, 2-glutamic acid
   c. 1-GUA, 2-valine
   d. 1-AUG, 2-methionine

3. The synthesis of an RNA molecule from a DNA template strand is
   a. replication
   b. transcription
   c. translation
   d. DNA synthesis
   e. Metabolism

4. RNA polymerase is primarily responsible for
   a. DNA replication.
   b. translation.
   c. transcription.
   d. transformation.
   e. polyadenylation.

5. Which of the following can NOT be an RNA transcript?
   a. AUGCGU
   b. ATGCCT
   c. UACCGA
   d. GCUUAC
   e. CACUAC

6. The first amino acid of a new polypeptide chain is
   a. AUG
   b. cytosine
   c. variable
   d. phenylalanine
   e. methionine
7. Transcription starts at a region of DNA called a(n)
   a. sequencer
   b. promotor
   c. activator
   d. terminator
   e. transcriber

8. ____ molecules carry protein-assemble instructions from the nucleus to the cytoplasm.
   a. template DNA
   b. ribosomal RNA
   c. transfer RNA
   d. messenger RNA
   e. none of these

9. In this depiction of transcription, the _____ strand is _____ because it ______.

   a. upper; RNA; is single-stranded
   b. lower; RNA; contains uracil
   c. lower; RNA; contains thymine
   d. upper; RNA; has no uracil
   e. lower; DNA; contains adenine

10. In eukaryotes
    a. transcription takes place in the cytoplasm, and translation takes place in the nucleus.
    b. transcription takes place in the nucleus, and translation takes place in the cytoplasm.
    c. transcription and translation both take place in the nucleus.
    d. transcription and translation both take place in the cytoplasm.
TOPIC 1: UNDERSTANDING AND RECOGNIZING UNITS OF MEASURE

Workshop Instructions – In the first part of the activity, Part A, you will first look at the metric system units and arrange the metric unit cards in order from the smallest unit to the largest unit. Next, you will take the given images of objects and place them on your metric number line next to the unit you think will best measure the object. Once you have completed this, you will take the English units of measure provided and place them next to the objects you have laid out according to what you think would best measure those objects. In the second part of the activity, you will examine several given objects and without measuring them, first put your estimate (guess) for how long the object is in both inches and centimeters. Once all your estimates are recorded, use the rulers provided to measure and record the actual lengths of the given objects. Once all measurements are recorded, use the following equation to determine your accuracy:

\[
\text{Accuracy} = \left| \frac{\text{Measured Value} - \text{Estimated Value}}{\text{Measured Value}} \right| \times 100.
\]

Manipulatives:

**Metric Unit Cards**

<table>
<thead>
<tr>
<th>$10^{-9}$ m</th>
<th>$10^{-8}$ m</th>
<th>$10^{-7}$ m</th>
<th>$10^{-6}$ m</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 nanometer)</td>
<td>(10 nanometers)</td>
<td>(100 nanometers)</td>
<td>(1 micrometer)</td>
</tr>
<tr>
<td>$10^{-5}$ m</td>
<td>$10^{-4}$ m</td>
<td>$10^{-3}$ m</td>
<td>$10^{-2}$ m</td>
</tr>
<tr>
<td>(10 micrometers)</td>
<td>(100 micrometers)</td>
<td>(1 millimeter)</td>
<td>(1 centimeter)</td>
</tr>
<tr>
<td>$10^{-1}$ m</td>
<td>$10^{0}$ m</td>
<td>$10^{1}$ m</td>
<td>$10^{2}$ m</td>
</tr>
<tr>
<td>(1 decimeter)</td>
<td>(1 meter)</td>
<td>(1 decameter)</td>
<td>(1 hectometer)</td>
</tr>
<tr>
<td>$10^{3}$ m</td>
<td>$10^{4}$ m</td>
<td>$10^{5}$ m</td>
<td>$10^{6}$ m</td>
</tr>
<tr>
<td>(1 kilometer)</td>
<td>(10 kilometers)</td>
<td>(100 kilometers)</td>
<td>(1 Mega meter)</td>
</tr>
<tr>
<td>$10^{-10}$ m</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Object Unit Cards

<table>
<thead>
<tr>
<th>Diameter of a flu virus</th>
<th>Wavelength of visible light</th>
<th>Diameter of red blood cell</th>
<th>Thickness of a penny</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>Diameter of a quarter</td>
<td>Distance between the knuckles of your index finger</td>
<td>Length of a baseball bat</td>
<td>Diameter of a DNA double helix</td>
</tr>
<tr>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>Length of a typical amoeba</td>
<td>Width of a wedding ring</td>
<td>Width of a single bit on a DVD</td>
<td>Length of a football field</td>
</tr>
<tr>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>Height of a typical pro basketball player</td>
<td>Length of an iPod</td>
<td>Distance a car can travel on the interstate</td>
<td>Length of an airport runway</td>
</tr>
<tr>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
<tr>
<td>Diameter of a soccer ball</td>
<td>Height of Mt.</td>
<td>Width of a large paperclip</td>
<td>Typical height of the back of a chair</td>
</tr>
<tr>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
<td>[Image]</td>
</tr>
</tbody>
</table>

### English Unit Cards

<table>
<thead>
<tr>
<th>1 inch</th>
<th>2 inches</th>
<th>3 inches</th>
<th>4 inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 inches</td>
<td>6 inches</td>
<td>7 inches</td>
<td>8 inches</td>
</tr>
<tr>
<td>9 inches</td>
<td>10 inches</td>
<td>1 foot</td>
<td>2 feet</td>
</tr>
<tr>
<td>1 yard</td>
<td>100 yards</td>
<td>&gt; than 100 yards</td>
<td>&lt; than an inch</td>
</tr>
</tbody>
</table>
Student Handout:

Understanding and Recognizing Units of Measure

Estimating the Length of Everyday Objects

Part A: To complete the first part of this activity you will need to locate the baggie of metric units, the baggie of English units, and the container of objects.
1. Take the units of measure in the baggie labeled “Metric Units” and arrange them in size order from the smallest unit of measure to the largest unit of measure.
2. Now remove the objects from the container and place them next to the metric unit you think would best measure that object.
3. Once you have your objects arranged next to your metric units, take the units of measure in the baggie labeled “English Units” and place them next to the objects, again choosing the unit that you think will best measure that object.

Part B: Complete the following section.
1. Without actually measuring the objects, estimate (guess) how long you think each object is. Fill in only the column labeled “I think it is…” for now!

<table>
<thead>
<tr>
<th>Object</th>
<th>I think it is…</th>
<th>Measured Value</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of this paper</td>
<td>_______ cm</td>
<td>_______ cm</td>
<td>_______ %</td>
</tr>
<tr>
<td></td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ %</td>
</tr>
<tr>
<td>Diameter of a penny</td>
<td>_______ cm</td>
<td>_______ cm</td>
<td>_______ %</td>
</tr>
<tr>
<td></td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ %</td>
</tr>
<tr>
<td>Length of a paperclip</td>
<td>_______ cm</td>
<td>_______ cm</td>
<td>_______ %</td>
</tr>
<tr>
<td></td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ %</td>
</tr>
<tr>
<td>Diameter of a CD</td>
<td>_______ cm</td>
<td>_______ cm</td>
<td>_______ %</td>
</tr>
<tr>
<td></td>
<td>_______ inches</td>
<td>_______ inches</td>
<td>_______ %</td>
</tr>
</tbody>
</table>
2. Now complete the column labeled “Measured Value” by measuring each of the objects.
3. Finish filling in the table above by calculating the accuracy of your values. To find accuracy use the following equation:
   \[ \text{Accuracy} = \left| \text{Measured Value} - \text{Estimated Value} \right| \div \text{Measured Value} \times 100 \]
4. Using your ruler, draw an ant that is 1 cm long here:

5. Using your ruler, draw a spider that is 1 in long here:

6. Compare the length of the ant (#4) and spider (#5) that you drew above. What do you notice about their size?
   Define a relationship between these two units of measure (i.e. make a conversion factor)?

7. How long is the pencil? Fill in the table: estimate, measure, and calculate accuracy.
8. How long is the cell phone? Fill in the table: estimate, measure, and calculate accuracy.

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Measured Value</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>_______ cm</td>
<td>_______ cm</td>
<td>%</td>
</tr>
<tr>
<td>_______ in</td>
<td>_______ in</td>
<td>%</td>
</tr>
</tbody>
</table>
**TOPIC 2: CONVERTING UNITS OF MEASURE VIA DIMENSIONAL ANALYSIS**

**Workshop Instructions** – You will be using the domino cards provided in order to complete the problems on your student handout. First, listen to a brief explanation of how the dominos work. These domino cards represent conversion factors. In order to illustrate problem solving by way of dimensional analysis you will first find the domino that says “start with.” In the space provided write the given number and unit of the problem you are working. Next you will arrange the domino cards so that your units of measure will cancel out. Once you units are in the correct places, fill in the corresponding conversion factors. Now you will transfer your pathway onto your paper and finish the math to reach your answer.

**Manipulatives:**

Domino Cards

For the sake of reducing the number of pages, this are sample representations of some of the domino cards that will be used for this activity.

---

**Student Handout:**
Converting Units of Measure

Using Dimensional Analysis to Convert Units of Measure

To complete the activity use the domino cards provided to convert the following problems. Begin by laying your domino cards out in the correct order displaying proper dimensional analysis methods and then transfer the pathway onto your paper.

1. Convert 5 pounds to ounces.

2. Convert 10 gallons to liters.

3. Convert 50 yards to meters.

4. How many hours are in a year?

5. A camper named Bob ran into aliens on a trail. Bob made friends with the aliens so he could steal their treasure of 1 zygot.

1 zygot = 3 trigots
3 trigots = 2 bigots
4 bigots = 1 gram gold

How many grams of gold did Bob take from the aliens?
Workshop Instructions – You will be using the various chemical molecules provided to construct a nucleotide. Once you have built all four possible DNA nucleotides, you will then show the base pairing that occurs between the purines and pyrimidines by showing where the hydrogen bonds will connect. You have a color sheet to remind you of what the overall outcome should be and you can color code your nucleotides with the handout provided.

Manipulatives:
DNA Coloring

The shape of DNA is a double helix, which is like a twisted ladder. The sides of the ladder are made of alternating sugar and phosphate molecules. The sugar is deoxyribose.

**Color all the phosphates PINK (one is labeled with a "P").**

**Color all the deoxyriboses BLUE (one is labeled with a "D").**

Color the thymines ORANGE.

Color the adenines GREEN.

Color the guanines PURPLE.

Color the cytosines YELLOW.

The hydrogen bonds are represented by small circles. **Color the hydrogen bonds GREY.**

**Note that the bases attach to the sugars and not the phosphate.**
Color the nucleotides below using the same colors as you colored them in the double helix.

1. Write out the full name for DNA. ________________________________

2. What is a gene? ________________________________

3. Where in the cell are chromosomes located? ________________________________

4. DNA can be found in what main organelle? ________________________________

5. What two scientists established the structure of DNA? ________________________________

6. What is the shape of DNA? ________________________________

7. What are the sides of the DNA ladder made of? ________________________________

8. What are the "stairs" of the DNA ladder made of? ________________________________

9. What is the name of the sugar found in DNA? ________________________________

10. How do the bases bond together?
    A bonds with ______  G bonds with ______

12. DNA is made of repeating units of building blocks called ____________________.

13. Why is DNA called the "Blueprint of Life"? ________________________________
TOPIC 4: TRANSCRIPTION/TRANSLATION

Workshop Instructions – Follow the instruction sheet that has been provided. You will first need to lay your template DNA strand down on the table in the proper direction and copy it onto your student handout. Next you will use the RNA nucleotides to perform transcription and create the mRNA stand that is complementary to your template DNA. Now you will take the tRNAs and place them so that the anticodons complement the codons on your messenger RNA. You will also use the codon chart provided to determine the amino acids being coded by each particular codon on the mRNA.

Manipulatives:
Instruction Pages

LAB _____: HOW ARE PROTEINS MADE IN CELLS

"DNA gets all the glory, but proteins do all the work!"

DNA is the molecule that stores the genetic information in your cells. That information is coded in the four bases of DNA: C (cytosine), G (guanine), A (adenine), and T (thymine). The DNA directs the functions of the cell on a daily basis and will also be used to pass on the genetic information to the next generation. Because of its critical role in all the functions of the cell, DNA is kept protected in the nucleus of your cells.

DNA is organized in sections called genes. Genes code for proteins, and it is proteins that do all the work in the cell. They function as structural proteins — serving as the building blocks of cells and bodies. And they function as enzymes — directing all the chemical reactions in living organisms.

Proteins are made in the cytoplasm by ribosomes. So the information from DNA must be transmitted from the nucleus to the cytoplasm. Each gene on the DNA is read and codes directly for a messenger RNA (mRNA) molecules. The mRNA is made by matching its complementary bases — C, G, A, and U (uracil) — to the DNA bases. The mRNA molecule then leaves the nucleus and carries the code for making the protein from the DNA gene to the ribosome in the cytoplasm.

The ribosome reads the sequence of bases on the mRNA in sets of three — the triplet codons. Another type of RNA — transfer RNA (tRNA) — brings the protein building blocks — amino acids — to the ribosome as they are needed. The ribosome bonds the amino acids together to build the protein coded for by the gene back in the nucleus.

PROCEDURE

1. Your group should obtain one sheet of paper with your four sections of DNA. Cut the strips out along straight lines and tape them together to make a long one-sided DNA molecule. Each section is numbered. Lay them out on the desk from left (#1) to right (#4). See the diagram below.

2. We are going to use this section of our DNA as a gene to make a protein the cell needs. Remember it used to be part of a double-stranded DNA molecule. But it has already been unzipped and now will be used as the template to build your mRNA, one base at a time. So first design an RNA polymerase enzyme to do this mRNA synthesis job.

3. TRANSCRIPTION: You have been supplied with mRNA nucleotide bases. Build a mRNA molecule from this gene by matching the mRNA bases to your DNA template, one base at a time. Tape this mRNA molecule along its length to simulate the strong bonds that the RNA polymerase makes between the mRNA bases. This way, it will be a stable molecule and can
Name

be moved off of the DNA to the ribosome for translation in the cytoplasm. Do **not** tape the mRNA to the DNA! Remember it has to leave the DNA in the nucleus and travel to the ribosome in the cytoplasm. Follow the diagram below.

4. To be ready for the mRNA in the cytoplasm, design your own ribosome to use in your simulation.

5. **TRANSLATION**: To help the ribosome do its job, use a pencil to draw lines which divide your mRNA into 3-base codons. Now obtain tRNA molecules and fill in the complementary anticodons to match so that they bring the correct amino acid to the ribosome. Use your mRNA-codon chart to help you. Fill in the name of the amino acid that is attached to the tRNA. Start reading the mRNA at the **START** codon and end at the **STOP** codon. Follow the diagram below.

6. As the tRNA matches the mRNA codons, cut off the amino acid from the tRNA and bond the amino acids together in a protein chain to simulate the action of the ribosome. Show your completed protein to your teacher for credit.

7. Use your DNA, your mRNA, and your protein to answer the Summary Questions.

**Teacher’s Initials**

---

Template DNA

mRNA Nucleotides
tRNA Molecules

SUMMARY QUESTIONS

1. Readily record the sequence of the DNA strand that you see in the first image.

2. Readily record the sequence of the DNA strand that you see in the second image.

3. Choose the mRNA sequence into its three parts and write them in order below as 3-base groups.

4. Record the anticodon sequence that this mRNA codes for. You can use the 3-letter amino acid abbreviations.

5. Record the mRNA anticodon that codes the amino acid to the mRNA.

MUTATIONS

Sometimes when DNA is copied, errors occur. We call these mutations. Sometimes mutations cause only minor changes to a gene and therefore make only minor changes in the protein produced from that gene. These types of mutations may cause only minor effects to the way an organism looks or functions — the phenotypes of the organism. But sometimes mutations can cause great changes to the gene and therefore greatly alter the protein that is made from that gene. This can have large effects on the organism, since the protein will not be able to perform its normal function. This may lead to the inheritance of a genetic disease.

6. One mutation is called a point mutation, where only one base in the gene is copied incorrectly during DNA replication. This would be an error of the DNA-building enzyme DNA polymerase. Here is your original DNA sequence from this lab:

   T A C G A C C C A C T G A G C T C C C C G A G C T C C C G A

   Below, retrace the original DNA sequence (from above), but let's simulate a point mutation at the 5'th base. It was accidentally changed during DNA replication from a C to a T.

   T A C G A C C C A C T G A G C T C C C C G A G C T C C C T

   Now transcribe this new DNA strand into mRNA, and then also translate it into amino acid sequences.

   T A C G A C C C A C T G A G C T C C C C G A G C T C C C T

   Did this change in the DNA sequence cause any significant change to the protein produced? Explain.
7. Now, again rewrite the original DNA sequence (from above), but let's simulate a **point mutation** to the 11th base. It was accidentally changed during DNA replication from a G to an A.

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
```

Now **transcribe** this new DNA strand into mRNA, and then **translate** it into its amino acid sequence.

```

Did this change in the DNA sequence cause any significant change to the protein produced? **Explain.**

```

---

8. Another group of mutations is called **frameshift mutations**, where at least one base is either added to or deleted from the DNA, as it is copied during DNA replication. This could be an error of the DNA building enzymes, DNA polymerase. Let's investigate the effects of these. Here is your original DNA sequence from this list:

```
T A C A G C C A C T G A G C T C C C G A G C T C C G A A C T
```

Below, rewrite the original DNA sequence (from above), but let's simulate a frameshift mutation by **adding** an additional base between the 5th & 6th bases. The base A was accidentally added to the sequence of the gene.

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
```

Now **transcribe** this new DNA strand into mRNA, and then **translate** it into its amino acid sequence.

```

Did this change in the DNA sequence cause any significant change to the protein produced? **Explain.**

```

---

9. Now, rewrite the original DNA sequence, but let's simulate a frameshift mutation by **deleting** a base at the 3rd base position.

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
```

Now **transcribe** this new DNA strand into mRNA, and then **translate** it into its amino acid sequence.

```

Did this change in the DNA sequence cause any significant change to the protein produced? **Explain.**

```

---
APPENDIX I – ANOVA Tables for Research Question 1 and Research Question 2

Topic 1

Tests of Between-Subjects Effects

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Topic 4

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APPENDIX J – ANOVA Tables for Research Question 3

### Topic 1

#### Tests of Between-Subjects Effects

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### Topic 3

#### Tests of Between-Subjects Effects

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### Topic 4

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