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A Quantitative Assessment and Comparison of Conceptual Learning in Online and Classroom-Instructed Anatomy and Physiology

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ABSTRACT

Online and virtual technologies have allowed higher education institutions to expand educational opportunities to a broader range of students. The number of students enrolling in online courses is rapidly accelerating, and therefore performance-based evidence of the effectiveness and equivalence of such courses to enhance student learning is necessary, especially in lab-based science courses – where research is currently lacking. This study compared conceptual learning of online and on-campus students in a two-semester anatomy and physiology course sequence. Two terms of students (N=397) completed standardized pre-test and post-test assessments designed to assess content knowledge and conceptual learning based on change scores before and after the intervention. Descriptive statistics were calculated to provide information on the background and equivalency of the groups with respect to certain learner variables, and a multiple regression model was used to assess the influence of learner variables on the knowledge-based assessment outcomes. The analysis showed that GPA significantly predicted performance on the learning assessment for the online treatment group, and GPA and the number of employment hours significantly predicted performance on the learning assessment for the on-campus control group. An Analysis of Covariance was used to examine the effect of course modality on learning. Both online and on-campus participants significantly improved their performance on the post-test, and there were no significant differences in learning gains between the groups. The results of this study suggest, and support previous research regarding online learning, that both online and on-campus instructional modalities can achieve the same conceptual learning goals in anatomy and physiology. The results of this study can be used to inform the ways in which learning in online anatomy and physiology courses parallels that of its physical on-campus counterpart, and prompt further research in this area. One of the most salient consequences of the present findings is the potential implications for higher education institutions regarding research, support, and transfer of online courses in the natural sciences, and further exploration of the potentials of such courses to attract and retain students.

A QUANTITATIVE ASSESSMENT AND COMPARISON OF CONCEPTUAL LEARNING IN ONLINE AND CLASSROOM-INSTRUCTED ANATOMY AND PHYSIOLOGY

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DEDICATION

This work is dedicated to the person who fills my life with joy, smiles, love-notes, laughter, inside jokes, movie quotes, high-fives, and happiness… my husband, Rob Humphrey.

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CHAPTER 1: INTRODUCTION

Statement of the Problem

In recent years, American colleges and universities have been trying to make higher education attainable to a broader range of individuals, as well as increase the learning opportunities available to matriculating students. Such strategies have included flexible time offerings to include evening and weekend courses, the development of nontraditional modalities to accommodate a range of learners, synchronous video-enhanced conferencing, hybrid/blended courses, distributed learning (communities), and most recently, fully-online asynchronous courses. Online learning system platforms as an instructional delivery medium are a rapidly advancing movement that included almost 7 million students in 2012, compared to just 1.6 million in 2002 (Allen & Seaman, 2013). This enrollment comprises approximately 32% of all higher education students (compared to just 10% in 2003), with community college students seeking Associate's Degrees making up the largest percentage of online students - greater than online students in all other types of institutions combined, including baccalaureate and graduate institutions. The growth rate of online learning across academia has outpaced the overall growth rate of students enrolling in higher education. Accordingly, as Allen and Seaman (2013) report, most higher education institutions, including both community colleges and four-year schools, consider online learning a critical institutional component.

With the focus in higher education shifting to expanding online options for students, there is also increased pressure on institutions to validate the effectiveness of their online courses. While significant growth of online learning has occurred in the last decade, studies have focused on the equivalency of technology-mediated (including hybrid and fully online courses) and on-campus courses in a number of disciplines, both in terms of student performance/learning and experience. Published research on secondary, post-secondary, and graduate courses cites arguments both for and against the efficacy of online instruction, however for the most part, there appears to be a general consensus that online education does not differ significantly from its face-to-face counterpart in terms of learning outcome attainment (Larson & Sung, 2009; Nguyen, 2015). A large number of recent empirical studies have compared online instruction with traditional face-to-face instruction in various disciplines. They have found that online students perform as well as (null findings), and in some instances better than, their face-to-face counterparts - arguing that there is no significant difference between modes of learning, and that online instruction can be as effective (or more effective) despite student learning style preferences (e.g., Aragon, Johnson & Shaik, 2000; Dell, Low & Wilker, 2010; Driscoll, Jicha, Hunt, Tichavsky & Thompson, 2012; Fish & Kang, 2014; Hart, 2012; Jones & Long, 2013; Lapsley, Kulik & Arbaugh, 2008; Ni, 2013; Shachar & Neumann, 2010).

According to a U.S. Department of Education (2010) meta-analysis of studies on online learning, on average, students in online environments did better than students in traditional environments. As a result, the U.S. Department of Education supports the expansion of online education. The evidence in support of the efficacy of online instruction is so strong that Larson and Sung (2009) argue that "it is a *foregone conclusion* that there is no significant difference in student learning outcomes between face-to-face versus online delivery modes" (p. 31). Thus, it has been demonstrated that learning can be equivalent across various instructional modalities, even if the modalities themselves are not equivalent in methodology. Notwithstanding, some traditionalists in higher education hold steadfast to the view that conventional face-to-face, synchronous instruction is a superior pedagogical mode (Allen & Seaman, 2013), and underrate the “no significant difference” phenomenon that has come to dominate publications in scholarly journals.

Teaching science courses at a distance has been described as more challenging than distance instruction in other disciplines (Kennepohl, 2009). Even as evidence mounts attesting to the effectiveness of online learning environments, there has been an unequal focus and emphasis on such environments across disciplines. There is a dearth in the number of online science courses as compared to online courses in other disciplines, such as education, business, computer science, and the social sciences (Flowers, 2011). A 2012 study utilizing a dataset of over 40,000 community college students in Washington State found that online courses tended to be less popular in natural science areas when compared to other disciplines, and that online natural science course enrollment constituted a low proportion of overall online enrollment (Xu & Jaggars, 2012). The fact that the pace of online science course offerings and enrollment are meager compared to online courses in other disciplines may be due in large part to the perceived lack of availability of sufficient virtual or remote labs – those approaches that involve technology-mediated instruction to facilitate learning the appropriate laboratory techniques and procedures – to completely replace a traditional hands-on lab experience. Experimentation is a fundamental component of the epistemology of science, and the methodologically empirical nature of science may be the most challenging part to deliver effectively at a distance (Kennepohl, 2009). Despite this obstacle, remote labs and virtual lab-based instruction has been around for some time (Baran, Currie & Kennepohl, 2004; Eick & Burgholzer, 2000; Kennepohl et al., 2005; Scanlon, Cowell, Cooper & DiPaolo, 2004).

Remote labs, technology-mediated virtual simulations, and take-home kits are used to complement, enhance, or even supplant face-to-face, hands-on laboratories. These options may be able to mirror the face-to-face experience in many ways. There are a number of examples of technology-mediated software and instrumentation, including National Instrument's *LabVIEW* system design, a commercially available software system that allows remote instrumentation control that has been used in academic engineering classroom settings for over 20 years (Kennepohl et al., 2005). Many publishers offer technology-based virtual labs and digital course support (for example, Pearson's *Mastering*, Cengage's *VitalSource,* and McGraw Hill's *Connect*). In addition, commercial companies are sprouting up that provide take-home, hands-on lab kits for online courses in a variety of science disciplines, including biology, chemistry, geology, and physics. For example, *eScience Labs* works with individual instructors to customize labs, providing all equipment, solutions, and tools for experimentation and dissection labs, and will deliver labs directly to students or work with college/university bookstores to allow students to purchase the kits using financial aid money. In addition, virtual dissection products/software/programs can be purchased, and some are provided at no charge from various educational organizations and animal welfare websites. Some of these products can be quite sophisticated, such as the Anatomage Virtual Dissection Table that provides an advanced 4-dimensional anatomy visualization system (Anatomage Medical). Despite the products available, exploiting the benefits of technology-based labs and implementing them in science courses has been slow, and not without criticism.

There are both proponents and detractors of online/virtual science courses. While the benefits of online learning are acknowledged by a majority of educators (Lim, Morris & Yoon, 2006), and a body of literature supports the effectiveness of online instruction, some higher education faculty and academic leaders have been reluctant to accept online learning as legitimate, and may perceive online courses as inferior to conventional face-to-face instruction (U.S. DOE, 2010).

Although the data are limited, a majority of studies in chemistry, physics, and biology have demonstrated that online science courses, as well as science courses that employ a virtual technology component, such as a simulated laboratory activity to augment existing course assignments, have educational value (e.g., Dobson, 2009; Gilman, 2006; Gonzalez, 2014; Johnson, 2002; Zacharia & Olympiou, 2011). In some cases, the learning gains exceed those of conventional face-to-face experiences (Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky, Reid & LeMaster, 2005; Hallgren, Parkhurst, Monson & Crewe, 2002; Reuter, 2009; Rifell & Sibley, 2005). In addition, some researchers have found that virtual course components, including labs, are generally well received and perceived by students (e.g., Sauter, Uttal, Rapp, Downing & Jona, 2013; Somenarain, Akkaraju & Gharbaran, 2010). It must be emphasized, however, that most of these studies do not focus on fully-online asynchronous learning environments, and therefore conclusions drawn regarding the benefits of online/virtual course components cannot be holistically generalized.

Unfortunately, many of the studies that explore the effectiveness of online instruction do not follow rigorous experimental designs, and consequently are not likely to stand up to scientific scrutiny. For example, without a control group, learning gains cannot necessarily be attributed to course modality (e.g., Hayes & Billy, 2002; Josephsen & Kristensen, 2006). Some studies focus only on anecdotal evidence, student self-reported perceptions of learning, and superficial analysis of learning via final grades or final exams as performance indicators, and not on broader items like student learning outcomes (e.g., Flowers, 2011; Friday, Friday-Stroud, Green & Hill, 2006; Taraban, McKenney, Peffley & Applegarth, 2004; Gonzalez, 2014; Somenarain, Akkaraju & Gharbaran, 2010). As such, descriptive studies and those that are limited to only student perception and/or final performance do not adequately address various areas of knowledge acquisition (without prior knowledge assessment), or take into account variations in course materials and course assignments, and thus can only draw weak localized conclusions and result in the inability to generalize the findings more broadly. Only a minority of studies appear to have employed a pre-/post-test design to measure changes in student understanding over time in each method. Without an adequate measurement of the variable of interest, psychometric characteristics of measurement cannot be adequately examined. Therefore, it can be assumed that greater reliability can be obtained from a study whose methodology: systematically and deliberately focuses on student conceptual learning; accounts for variability across the groups to control for confounding variables, mitigating factors, and selection effects; incorporates multiple sections of the same course(s) offered over multiple terms/semesters; uses a valid instrument for measurement; and incorporates analyses using multivariate regression.

Theoretical Framework

Tallent-Runnels, Thomas, Lan, Cooper, Ahern, Shaw, and Liu (2006) reviewed and summarized the research conducted on online teaching and learning in both graduate and undergraduate environments. They found “no comprehensive theory or model that informed studies of online instruction” (p. 115). This echoes the sentiment of the U.S. Department of Education, that the field of online learning “lacks a coherent body of linked studies that systematically test theory based approaches” (2010). Upon review of the literature, it is clear that internet-based learning theorists and researchers have yet to develop a widely accepted and cohesive conceptual framework grounded in existing knowledge contexts to serve as a foundation of education theory for planning and implementing instructional design and activities for online instruction. Given the growth rate of online course offerings and the current number of students enrolled in at least one online course, a model to predict and explain how people learn online is needed.

There is a relationship between instructional theory and its dependent technologies (Cooper, 1993). Educational theory must address both the advantages and constraints of the online learning medium and instructional software. In their book, *Theory and Practice of Online Learning*, Anderson and Elloumi (2004) emphasize that, although there is no one school of thought that constructs the foundation for online learning, one can use a combination of theories regarding the different approaches to learning that will "motivate learners, facilitate deep processing,…promote meaningful learning,…[and] facilitate contextual learning" (p. 6). The authors assert that online learning involves principles from three different learning paradigms:

Behaviorism, a paradigm that contends that observable behaviors indicate learning, operating on a principle of stimulus-response (Skinner, 1974);

Cognitivism, a paradigm that progressively replaced behaviorism and contends that learning involves mental activities and internal processing capacities, including memory, motivation, and reflection to form knowledge as a mental construction (Craik & Lockhart, 1972); and

Constructivism, a paradigm that contends that learning is not passive, but instead learners subjectively interpret information according to their personal reality and personality dimension, and actively construct their own representations, linking prior knowledge with new knowledge (Duffy & Cunningham, 1996; NRC, 2005).

Increasingly innovative technologies alone cannot make learning more efficient, and instead their use and implementation requires incorporation of foundational learning theories to the design of online materials. Anderson and Elloumi (2004) outline the implications for online learning environments that underlie each school of thought regarding learning theory. They conclude that online instruction can successfully promote learning if certain criteria are met with regards to behaviorism (e.g., explicit statement of learning outcomes, integrated assessments, feedback) (p. 8), cognitivism (e.g., strategies to maximize sensation and facilitate the use of existing schema, present information to facilitate efficient processing, promote higher-level learning, accommodate different learning styles, include intrinsic motivation strategies, and encourage application to develop personal meaning and contextualization) (p. 9-17), and constructivism (e.g., incorporate meaningful and stimulating activities, allow learners to construct their own knowledge, provide time for reflection, and allow for interaction with the content and other learners) (p.18-20).

Views on adult learning theory have largely shifted from instructivist teacher-centered perspectives to constructivist learner-centered perspectives. This evolution has implications for the development of online courses, as this theory does not emphasize the necessity of a synchronous face-to-face environment for meaningful learning to occur. However, in order to facilitate optimal learning guided from constuctivism, a number of factors must be implicitly considered in regards to course design. In a more recent publication, Draus, Curran, and Trempus (2014) ascribe Lipman's (1991) community of inquiry framework as "the primary theoretical framework for understanding the nature of the relationship between online instruction and learning" (p. 241). This view recognizes behavioral psychology and the constructivist concept of social cognition to be particularly relevant in an online learning context, and also integrates Anderson and Elloumi's (2004) assertions regarding cognitive theory for an online learning environment. It emphasizes the role and interactions of the educator and the student for how learning occurs in an online environment. Shea and Bidjerano (2009), in their examination of theories regarding technology-mediated education, state,

> The community of inquiry framework (CoI) focuses on the intentional development of an online learning community with an emphasis on the processes of instructional conversations that are likely to lead to epistemic engagement. The model articulates the behaviors and processes required to nurture knowledge construction through the cultivation of various forms of ‘‘presence”, among which are teaching, social, and cognitive presence...[This model] emphasizes the needs for online learners to be able to address the challenge of projecting themselves as ‘‘real people.” This facet of the model is significant for online education in that face-to-face interaction, and the conventions of non-verbal communication that underlie a great deal of the flow of instructional conversation (and understandings that emerge from it) is often not possible, especially in the dominant form of online learning, asynchronous learning networks. The model assumes that this is a necessary component of a productive community of inquiry and that the online instructor is responsible to foster an environment of satisfactory social presence (p. 544).

Here, forms of “presence” foster and cultivate collaboration that allow the construction of knowledge. A community of inquiry model involves interaction of three core elements - social presence, cognitive presence, and teaching presence; whereby each form can be seen as overlapping and combining within a community of inquiry (Garrison, Anderson & Archer, 2000). If these elements are maintained in an online setting, learning is supported. Consequently, how a course is designed and how the technology is used to create the learning environment is “paramount” in achieving learning outcomes (p. 92). Critical to this framework is specific instructional design and organization that involves instructor presence, which in turn facilitates online communication. In this capacity, a community of inquiry is created whereby students bear responsibility for their own learning based on experiences and interactions within the online environment (Draus et al., 2014). In this way, learning involves interactions that foster learning through instructors' guidance and in collaboration with peers. As MacQueen and Thomas (2009) point out, methods of delivery that create a social context for learning contrast with the impersonal nature of past (and outdated) correspondence modes of instruction. Therefore, advanced technologies that provide both synchronous and asynchronous interaction and discourse components can overcome the barriers to interactions among learners (Huang, 2002). Online environments can provide the learner with greater freedom of control, which contrasts with traditional methods of content delivery, while simultaneously integrating constructivist principles and student-centered adult learning theory.

The community of inquiry framework of education theory provides a basis for, and supports the learning occurring in, online and virtual environments. The basis of this framework is most relevant and applicable to the constructs explored in this study, as it provides for the integration of technology-mediated instruction, individual responsibility, constructivist-centered principles, and course presence to support and enhance conceptual learning in asynchronous online learning environments.

Purpose of the Study and Research Questions

The trend in popularity of online courses is expected to continue (Allen & Seaman, 2013). As such, there is increasing demand for online education offerings, including lab-based natural science courses. Science education has traditionally been centered on hands-on experiences to promote student engagement and understanding; however, the landscape of biology laboratories is changing rapidly as technological advances have made it possible to perform a variety of labs virtually. Empirical studies that compare online and face-to-face learning environments are, in fact, comparing environments that are quite dissimilar. Johnson, Aragon, Shaiek, and Palma-Rivas (2000) describe this as “a classic example of comparing apples to oranges” (p. 31). Therefore the purpose of this study is not to ascertain equivalency in all aspects, but instead to determine if online and traditional face-to-face courses share the same conceptual learning outcomes.

There exists a significant need to gather empirical, performance-based evidence regarding suitable and effective pedagogical and curricular approaches to teaching science. This includes analyzing the utility and efficacy of fully-online post-secondary majors’ biology courses and their concomitance with quality standards of education, including research on anatomy and physiology courses. Surprisingly, research comparing learning in asynchronous fully-online anatomy and physiology courses with traditional face-to-face anatomy and physiology courses is severely lacking. The purpose of this research is to attempt to close the gap in the scholarly literature, and specifically, to determine if fully-online lab-based anatomy and physiology courses can achieve the same learning goals as traditional face-to-face anatomy and physiology courses, while meeting institutional quality standards. The results of this study will have a significant impact on institutional policies regarding online course offerings and transferability of online lab-based science courses, as well as the sustainability of online programs for science majors. Therefore, the present study addresses the following research questions:

1. How does conceptual learning in fully-online courses compare with that of traditional face-to-face classroom/lab courses as measured on a standardized conceptual learning assessment?
   Sub-Question 1.1. Do the subject variables that influence student learning in online versus traditional biology courses differ?
2. How does overall grade distribution compare between fully-online and traditional face-to-face students?

Significance of the Study

In a national study involving thousands of U.S. community college students, Shea and Bidjerano (2014) examined degree completion rates among students enrolled in distance education courses during their first year of study at a community college with the rates of their on-campus classroom-only counterparts. The authors found (to their own surprise) that students who take some of their early courses online have a significantly better chance of degree completion when relevant background characteristics (including socio-demographic data, type of college, and goals) are controlled for. The authors propose that an online learning environment enabled something they call "transactional adaptation." They suggest that "adaptation" occurs whereby online courses as part of a flexible degree pathway enable college students to integrate more successfully "in the academic, social, psychological, professional, and familial dimensions of college participation" (p. 104). Thus, the internet may be a pervasive factor in terms of student retention. The results are surprising, given that community college online course and program offerings have seen substantial growth, but that growth has been concurrent with unprecedented low graduation rates. Despite this, they found that attainment of a community college credential is more likely to occur if early participation in an online learning environment occurs. The authors emphasize that this appears to hold true for all students in their national sample, regardless of the fact that students deemed as high risk for not attaining a degree were over-represented in the sample (indicated by the National Center for Education Index). They believe the data support ongoing investment into online learning as a form of access to a college degree.

Technological advances have changed the landscape of biology laboratories, yet there is no universal consensus on the efficacy of online biology courses. Recently, the State University of New York (SUNY) created Transfer Paths that "summarize the lower division requirements shared by all SUNY campuses for similar majors within most disciplines" (SUNY website). As indicated in the SUNY Seamless Transfer Resolution Memorandum, successful student transfer within SUNY has been "a central theme in policies and strategic and master plans… since 1972" (p. 1). The recommendations present in many of the biology-related transfer paths contradict these goals. The Seamless Transfer Resolution states "seamless transfer permits students to complete a degree without duplicative effort or unnecessary costs" (p. 1). The requirements initially mandated that biology courses with a lab component are not transferrable to other SUNY institutions if taken online, despite the courses being successfully completed at a SUNY institution. Adhering to this requirement could place students in these paths at an unnecessary disadvantage.

The constraint that biology courses may not be taken online contradicts the shift to online learning environments and the Open SUNY Proposition, which proposes to "expand… online education and foster innovation in teaching and learning" and to "increase the number of online learners" (p. 1). The Open SUNY Proposition states that SUNY has the potential to be "America's most extensive distance learning environment" (p. 3). Contradictory to their stance on online science course transfer, in 2016 SUNY awarded a four-year SUNY Environmental College almost $200,000 to be used to establish online-enabled STEM-focused programs. Thus, their transfer mandate appeared to be put in place despite a lack of performance-based evidence, including evidence either in support of or against fully-online biology learning, and their allocation of funds appears to repudiate their lack of support for online science learning. As introduced in this section and more thoroughly explored in the next, contradictory evidence has demonstrated that students exposed to virtual/distance/online components performed equivalently to their face-to-face counterparts. Additionally, some studies have shown that integrating a virtual online component enhances student outcomes (e.g., Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky, Reid &LeMaster, 2005; Hallgren, Parkhurst, Monson & Crewe, 2002; Reuter, 2009; Rifell & Sibley, 2005). This, in combination with the data provided in the national study conducted by Shea and Bidjarano (2014) regarding the correlation between attainment of a community college degree and registration in online courses, supports, at the very least, further investigation into the matter.

In 2014, due in part to opposition from biology faculty at some SUNY institutions, the Biology Transfer Pathway restrictions placed on online anatomy and physiology and other biology courses were lifted. Instead, supplementary “Advising Notes” included the statement, “Unless otherwise noted, courses that include online labs are not currently guaranteed for transfer across all campuses. Those courses and their online labs may be evaluated for transfer on a case-by-case basis by the receiving campus” (SUNY Biology Transfer Path, p. 3). Based on the limited current research regarding online biology laboratory courses, there does not appear to be a substantive or pragmatic argument to support non-transferal of online science courses. The initial mandate, although subsequently revised, seems antiquated given the advances in distance/virtual learning technology, enrollment trends, and available literature regarding online learning. Without evidence to support non-transferability, restrictions on course transfer within the SUNY system present an unnecessary and arbitrary hurdle to student completion of their degree programs. This, in combination with pressure on institutions for a greater level of institutional accountability and assessment, has made research in this field particularly urgent.

As a result of the increasing focus on online/virtual learning environments, and the recent, albeit provisional, restrictions imposed on online biology course transfer by the SUNY system, it is imperative that further investigation into online learning and performance be completed. Such research should be conducted in an online anatomy and physiology course at a two-year SUNY school (whereby a majority of credits are taken with the intention of transfer, especially anatomy and physiology courses). Despite the successful contribution of online education in other disciplines, and the abundance of literature on online learning in general, there has been very little investigation into learning in online science courses – resulting in a paucity of data regarding online science courses. The data generated from this present research can have a significant impact on SUNY policy as well as influence similar transfer policies at other institutions, but most importantly, it can be used to help all college administrators, admissions counselors, and faculty make decisions regarding program and curriculum development, student advisement, distance education offerings, global marketing strategies, and course transfer/acceptance – policy decisions that can have an enormous impact on students, both academically and financially.

Definition of Terms

The following are the operational definitions for the purpose of this study:

Online or E-Learning or Virtual or Web-based Course: A subset of distance education whereby the learning environment lacks a face-to-face interaction component, and all learning activities, access to the materials and content, and assessments are completed through some form of technology such as an online management system as a *replacement to* and not *enhancement of* traditional face-to-face instruction. In an asynchronous online learning environment, learning and communication can occur at different times, across different regions, and across different time zones. This paper will use the term "online" throughout.

Traditional or Face-to-Face (F2F) or On-campus Course: A course in which students and the instructor are in the same place at the same time and therefore learning occurs in a real-time synchronous environment.

Hybrid or Blended Course: A course that incorporates a multifaceted approach with multiple modes of delivery of course content, including both a virtual online component and a face-to-face component. Students learn in both synchronous and asynchronous modes.

Ma and Nickerson's (2006) definitions will be used to differentiate hands-on labs, remote labs, and virtual/simulated labs:

Hands-on or Traditional or Wet Lab: Laboratory procedures that involve a physically real investigative process; both students and lab equipment are present.

Simulated or Virtual Lab: Laboratory procedures characterized by their involvement of imitations of real experiments simulated on computers.

Remote Lab: Laboratory procedures characterized by the physical separation of students and equipment; experimenters obtain data by controlling equipment that is geographically detached.

Anatomy & Physiology I (A&PI): The first 4-credit lab-based course in an Anatomy and Physiology sequence. Units within the course include cells, tissues, integumentary system, skeletal system, muscular system, nervous system, and special and somatic senses.

Anatomy & Physiology II (A&PII): The second 4-credit lab-based course in an Anatomy and Physiology sequence. Units within the course include digestive system, endocrine system, cardiovascular system, respiratory system, lymphatic system, immune system, urinary system, reproductive system, and water/electrolyte/acid/base regulation.

SUNY: The State University of New York, the largest comprehensive state-supported university system in the United States, comprising 64 institutions.

SUNY Transfer Pathway: Common lower division requirements shared by all SUNY campuses for similar majors within most disciplines.

Blackboard (Learning Management System - BLMS): An online (web-based) learning management system designed to support fully-online courses or provide a platform/medium for course supplementation. Blackboard software applications provide tools to deliver content and assess student performance.

Learning Outcomes: Statements that specify measureable or observable knowledge, skills, or attitudes that learners should possess as a result of a learning activity.

Conceptual Learning: Development of a content knowledge base with an in-depth understanding of concepts, a multidimensional integration of information into the learner's conceptual framework, and a connection to broader ideas and principles (Tanner & Allen, 2005).

Delimitations

This study was confined in scope to undergraduate students enrolled in 200-level anatomy and physiology I and II courses at a two-year community college. In a comparison study of this nature, group equivalency is an important consideration. True experimental design was not used, as students self-selected their learning modality and therefore were not randomly assigned to groups. Although the sampling frame was representative of its intended population and assignment to groups occurred naturally (thereby not disrupting the existing and natural education setting), the sample is not truly representative of any population.

Gains and differences in conceptual learning of undergraduate students were considered in this study. The pre-/post knowledge-based assessments utilized in this study included questions that assessed learning limited to knowledge-, comprehension-, and application-level cognitive domains. Higher-order cognitive domains assessing critical thinking were not considered in this study, and therefore the results of this study are not generalizable to learning in every capacity. As this was modality-centered research, other variables such as attitudes about learning and satisfaction (student's perception of the experience and perceived value) were not explored. In addition, laboratory procedural/operational skills were not assessed in this study, and therefore no conclusions can be drawn relating to laboratory skills and how conceptual learning in online anatomy and physiology translates to applied and clinical practice.

Limitations

The site where the research was conducted has an open enrollment policy, and therefore the site population may not be representative of the typical college/university population in the United States. The institution has a higher proportion of female students and nontraditional students. In addition, there is not substantial ethnic/racial diversity, as a large percentage of students at the institution identify as white (2015-2016 College Catalog; Diversity Report, 2012). For these reasons, the results of this study may not be generalizable to all students, and the external validity is limited in strength.

This study was limited by the willingness of participants to complete all assessment instruments. Unless all three assessments were completed and submitted, the student's data were omitted from analysis. In addition, it is possible that some participants did not put forth maximal effort when answering questions on the pre- and post-test knowledge assessments and therefore their earned scores would not be accurate reflections of their conceptual knowledge at the start of and upon completion of the course. Additionally, as participants did not complete the assessments under the supervision of a proctor, it is possible that the work submitted was not the legitimate and truthful effort of the student.

This study included 33 sections taught by 14 different instructors. On-campus sections in this study were taught by seven different instructors. On-campus sections lacked standardization of assessments and activities in each section. Therefore, instructor effects, which were not explored in this study, may have influenced learning and could be responsible for differences in scores on the knowledge-based assessment exams among sections.

Test validity, based on whether the pre-and post-tests are measuring what they were designed to measure, was determined during post-hoc correlation analysis, and the pre- and post-test performance were found to be correlated. The questions were crafted using standardized questions created by *The Human Anatomy & Physiology Society* (HAPS), an international professional organization, and were investigated for psychometric properties including validity and reliability. Test/retest effect can potentially occur as a threat to internal validity, however, a timeline was established to minimize this effect, and the between-test interval was maximized. In this study, the most likely threat to external validity was treatment and testing interaction (Keppel, 1991, p. 84-85; Marsden & Torgerson, 2012). This may occur if exposure to the pre-test triggered a change in focus or behavior, which may have influenced scores on the post-test, thereby increasing or decreasing the observed effects of the teaching intervention.

Since group assignment was nonrandom (and therefore lacks characteristic equalization), this research was more sensitive to internal validity problems. By virtue of student's selection of learning modality, this research is subject to selection bias, whereby characteristic differences between the groups may be responsible for observed change rather than the teaching intervention, as the effects of the teaching intervention in this case cannot be truly isolated (Dimitrov & Rumrill, 2003; Nguyen, 2015). In a pre-/post-test design, regression to the mean is a threat to internal validity, however, a large sample size minimizes this threat (Keppel, 1991; Marsden & Torgerson, 2012). A power analysis was conducted in order to determine the appropriate sample size and protect against regression effects.

An additional threat to internal validity deals with prior biology coursework experience, as this may influence a student's scores on one or both of the assessments. This, along with other group characteristics, was controlled for and addressed by using regression analysis during the data analytic portion of this study. However, no distinction was made regarding the level of science coursework completed prior to taking anatomy and physiology (high school or college-level, majors or non-majors), only the number of courses. Thus, though the demographic questionnaire surveyed students' prior biology course experience, it did not make a distinction between levels of coursework, and therefore conclusions based on science background as a predictor for student learning are limited. The demographic questionnaire required students to self-report their GPA, which could potentially result in response bias, which would thereby impact conclusions drawn from regression analyses; however to minimize this risk, a post-hoc analysis was conducted comparing reported GPAs to institutional GPAs (from the following academic term), and subsequently were found to be reliably reported.

An additional limitation of the study includes the degree of variation in instruction and learning activities. This is most applicable to the on-campus sections, as the online sections were more rigidly standardized insofar as breadth, depth, sequence of coverage, labs performed, and number and types of assessments. There were numerous on-campus sections included in this study taught by different instructors. Institutional constraints prevented rigid standardization of learning and teaching activities in each section. The course materials and the content covered in each course is prescribed by the biology department and therefore is universal in each section, regardless of modality, however, learning activities and pedagogical methods varied by instructor (Table 1). Major differences include animal specimen dissections (seven on-campus sections used pigs for dissection and ten sections used cats) and use of virtual laboratories (four on-campus sections utilized in-class computer-mediated experiments in a synchronous computer lab environment, while the others used wet lab versions of the same lab). Such variation in content delivery, pedagogy, and type, number and quality of assignments could potentially influence learning; however, minor variations are not likely to affect conceptual learning in any significant way.

Ethical Considerations

The protocols used in this research were approved by Syracuse University's Institutional Review Board (Appendix A). (This research was conducted in compliance with and with approval from the study site's IRB, however the approval form was purposely withheld from the appendix to maintain site confidentiality.) It was unlikely that this research strategy caused emotional, physical, social, or political risks to participants, other than the increased risk of test anxiety and a time commitment; however, as this research involved the transmission of data through an online management system, there was the risk of compromising privacy and/or confidentiality. Therefore, appropriate measures were taken to ensure that confidentiality was maintained. The data were aggregated and no individual identifiers were used in any report generated from this data. Individual student data were not reported, and instead pooled data on assessment performance from both types of class modalities (online and on-campus) were compared. The principal investigator assigned a number to individual student responses, and only the researcher had the key to indicate which number belonged to which participant. The data that were collected were kept on a secure, password-protected file on a password-protected desktop computer in a private office at the research site.

CHAPTER 2: LITERATURE REVIEW

Overview

This chapter reviews the scholarly literature relevant to the study of online learning in science classes. It begins with an overview of existing research that examines student learning in, and perception of, online science courses, including both lab and non-lab courses. This is followed by a comprehensive analysis of the role of online/virtual media to enhance student conceptual learning in biology, specifically anatomy and physiology, and concludes with an overview of the reported advantages and disadvantages of online instruction.

Comparison of Traditional and Online Science Courses

Although online learning has been researched heavily in the last decade, there have not been widespread research efforts or focus on fully-online course experiences in post-secondary lab-based natural science courses, specifically biology. This finding is concomitant with the lack of online science course offerings overall. Instead, most of the research has been conducted in K-12 classrooms or post-secondary non-science majors' courses. In addition, those researchers who have explored this topic have traditionally integrated blended models, or "hybrids," that incorporate virtual labs as supplementation and enhancement, but not *replacement*, to the traditional wet lab experience. Thus, discrete portions of courses are taught using technology-assisted virtual/simulated/online resources, often limited to one or only a few modules of the curriculum, instead of investigating full-term online courses.

As stated previously, there is a paucity of research conducted specifically on online science courses. However, what does exist supports the development and implementation of online courses and virtual labs in post-secondary science courses, and affirms their utility. There are many studies that focus on student success and learning in online/virtual courses, however, evaluation of the effectiveness of online/virtual science courses in achieving learning goals is far less prevalent.

In 2012, the Colorado Department of Higher Education conducted a study comparing students enrolled in the Colorado Community College System in traditional and online science courses. The first part of this study was a comparison study, and focused on the differences among students enrolled in science classes (biology, physics, chemistry) in either the online format or traditional format (N=4,500). Their analyses showed that students enrolled in online science courses had higher GPAs but slightly lower average grades in science courses compared to traditional students. Statistically significant differences were found among the type of science class and average science GPA, overall GPA, and cumulative credit hours, and demonstrated that physics students performed slightly higher than biology and chemistry students. The authors suggest more research is needed to interpret why higher GPAs and higher average cumulative hours were observed in online science students. Although this study did not focus on learning gains, it provides insight as to the type(s) of learner variables that may influence success and enrollment in online science courses, despite the lack of grade standardization. The second part of the study tracked and compared average science GPA of those online and traditional students who subsequently attended a four-year institution. No significant differences were found between the community college instructional delivery modality and success at four-year institutions, suggesting that students enrolled in online courses performed just as well in science classes at four-year institutions as those who enrolled in traditional on-campus courses.

In an early study involving online biology, Johnson (2002) focused on the ability of an online environment to facilitate achievement of learning objectives in a nonmajors' introductory biology course using hands-on, inquiry-based labs that students conduct at home. This quasi-experimental research design was conducted over the course of two semesters. Two online sections were compared with an on-campus section, all taught by the same instructor. The pedagogical approach for the on-campus section is described as "an inquiry approach in both lecture and lab" (p. 313), but very little detail is provided regarding specific activities. The online students were required to develop and test hypotheses by conducting activities described in the lab manual (using take-home kits and additional store-bought items), and were required to graph the data and submit their work. Students also developed alternative hypotheses and described how they would test them in weekly asynchronous bulletin board discussions. Weekly online quizzes were used for continuous assessment. Johnson found that online students were as successful as on-campus students "at acquiring an understanding of biology content…and increasing reasoning ability" (p. 314). The results of the study revealed no significant difference in final exam scores between the classes, and no statistically significant differences in learning outcomes. In addition, an attitude survey revealed that students in both groups expressed relatively positive attitudes about biology. A limitation of this study includes the method of assessing prior knowledge. The same pre- and post-tests were not used, and instead a pre-test based on textbook publisher questions was used to assess understanding of biological concepts prior to the course, and the post-test was a National Association of Biology Teachers Biology Examination from 1987, which is outdated even for a study published in 2002. These assessments were not field-tested, and the reliability and validity of the questions had not been determined.

A critical issue of using virtual/simulated labs in a science course is whether or not the use of the actual laboratory equipment has a greater effect on learning, as well as on students' general experience. Gilman (2006) compared student attitudes and learning when performing an online/virtual versus traditional in-class version of a cell division lab exercise in a college-level freshman biology course. The study involved 54 students completing the in-class experiment and 52 students completing the online experiment. The online students were required to read the same lab manual background information associated with each activity that the traditional students had, sketched the process of mitosis and meiosis based on online images, and used an interactive website to perform the rest of the lab. The traditional class section used pop beads to simulate the process of cell division. In-class quizzes were administered to both groups one week following the lab exercise, and comparison of student quiz scores revealed that students demonstrated increased understanding of the lab content when the online virtual cell division lab was performed. Student responses to a voluntary survey indicated that the online lab students "got just as much content knowledge out of the lab in a much shorter time, and with minimal interaction" (p. 133). A strength of this research is that the participants were randomly assigned into online and in-class groups, however, a pre-/post-test research design was not implemented, and therefore there is no way to ascertain knowledge gain over the course of the term of the semester. An additional issue with the study design was the lack of clear explanation of how the quiz questions used to determine comprehension were developed, which ultimately impairs the validity of the dependent measure. Finally, because three different lab instructors were involved in the research study, it is unclear if the students in the sections had identical experiences based on standardized curricula, and therefore some discussion of inter-class evaluation or analysis would have been enlightening.

As a result of low attendance and poor performance in traditional face-to-face courses, Rifell and Sibley (2005) developed a hybrid course with the aim of improving the effectiveness of an introductory environmental biology course. Two out of three hours of lecture time were replaced with bi-weekly online homework assignments, and for the other hour, the class met face-to-face for lecture instruction and active-learning exercises. To assess the effectiveness of the hybrid course, a traditional lecture format version of the same course was taught concurrently. Both the traditional lecture version and the hybrid version covered the same subject matter, included the same active-learning exercises, and were taught by the same instructor. There were 74 participants in the traditional lecture course and 55 participants in the hybrid course. A survey was administered at end of the course to collect participant demographic data, self-reported measures of effort, and student perceptions of the course. Participant demographics were similar in both sections. Attendance was monitored and performance and effort were calculated based on earned scores on completed activities. Learning gains were assessed using a pre-/post-test design that included questions that covered course content as well as procedural knowledge. Overall, students in the hybrid course performed significantly better on assessments and earned higher grades. The hybrid course format improved the amount of active learning and effectiveness of classroom-based assignments. The authors caution that while most students performed better in the hybrid section, the hybrid format may not facilitate learning for all types of learners. Since enrollment was open for both types of courses, student populations were self-selected. Additionally, the researchers did not describe how the pre-/post-test questions were developed, whether they were previously field-tested, or if they established reliability or validity for the questions.

Whether students derive realism from a technology interface instead of a hands-on lab can be difficult to measure. Sauter, Uttal, Rapp, Downing, and Jona (2013) asked physics students to compare two types of labs. The authors wanted to examine the learning implications of using simulated labs, whereby computational models generate data, and remote labs, whereby there is computer-mediated access to real experimental devices. Their goal was to determine how such labs affected the students' experience. The researchers randomly assigned 123 undergraduate students to one of two groups, one group completed a physics lesson that was presented remotely and the other group performed a simulation. Students completed computerized pre-test and post-tests that included content questions as well as procedural questions. Students were then interviewed to assess their thoughts about their experience with the lab. Participant perceptions and attitudes regarding the realism of the labs were collected via a survey, specifically to determine if students felt like they were doing real science using computer technology simulations with interfaces and visualizations that "lend a sense of presence to the experience" (p. 38) despite not physically handling scientific instrumentation. The length of the lab activity and the timeframe between the pre- and post-test is not identified and therefore test effect may have influenced scores on the post-test. The students who completed the remote labs were more likely to respond that they felt like they were conducting a real experiment; however, based on assessment measures, both the remote lab and simulation modalities were effective at teaching the target content. The authors conclude that the lab interface and visualizations were especially important in creating a realistic lab experience, and that their implementation can optimize student learning. The assertion that the most desirable simulation design should include all available means of increasing the impression of "presence" (Scanlon et al., 2004), supports the conclusions of an earlier study regarding the realistic representation provided by virtual labs and the opportunities they provide for situational learning (Harms, 2000).

In a 2005 study, Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky, Reid, and LeMaster examined the effects of substituting a computer simulation for a hands-on laboratory experience in an introductory physics course. Fifteen sections of algebra-based introductory physics were split and divided into either a traditional or a computer-simulated condition. Data were collected on the amount of time it took students to complete each lab, the answers provided on student write-ups, and scores from a final examination. The test and control conditions were identical for all groups except for the use of computer simulations in the experimental groups. The results of the study indicated that students who used computer simulations instead of physical equipment performed better on conceptual questions. The authors concluded that, if properly designed, simulations are useful tools to promote student learning. This study included a large number of participants and sections, and although different teaching assistants and instructors taught the sections, their assignment was purposefully and strategically allocated to isolate instructor/TA effects. However, there were no pre-assessments to gauge experience with the lab content and instrumentation. Furthermore, the experimental groups were provided with online background information on the lab equipment and experimental procedures upon arrival at the laboratory, but the control groups were not. As a result, the TAs of the control and experimental groups reported a distinct difference in their use of time during the lab activities, and one of the experimental group assistants reported that, compared to his/her previous “chaotic” experiences with the lab (using physical equipment), the simulation lab environment was “calm and composed” (p. 4).

In a similar study, Zacharia and Olympiou (2011) compared virtual versus physical manipulative experimentation in a physics class. The lab was divided into four experimental conditions and a control group. Each group used the same inquiry-instructional method and curriculum on parts of the lab, but the experimental groups conducted those same parts virtually instead of with physical equipment. The authors found that different experimental conditions involving varying degrees of virtual experimentation were equally as effective in promoting conceptual assimilation in a physics course. They used a pre-/post-test research design to investigate whether the groups had differences in the outcome measures of each test. Their analyses revealed that physical manipulation of laboratory equipment is not a requirement for learning and understanding physics concepts. Strengths of this study include that students were randomly assigned to groups, all students followed the same curriculum, and all students in the study shared similar backgrounds in physics. However, a limitation of this study deals with the timeframe of data collection. The experimental sections were not run concurrently and data were collected two years before the other groups without test standardization, weakening the validity of the conclusions.

In an earlier study, Zacharia (2006) investigated the effects of combining a traditional lab involving hands-on physical manipulation of equipment (real experimentation) with virtual experimentation in a physics course. In this study, 90 undergraduate students were randomly assigned to either a control group that used real experimentation, or the experimental group that used a combination of both virtual and real experimentation. A pre-/post-test comparison study design was used to compare learning gains for each group, and the analysis revealed that the students who utilized a combination of virtual and real experimentation had significantly higher post-test scores than the students in the control group who performed real experimentation only. This finding suggests that the combination of traditional hands-on and virtual experimentation has a stronger effect on conceptual understanding than hands-on experimentation alone. The author asserts that this evidence supports the conclusion that using virtual labs, either in combination with traditional experimentation or alone, could promote student conceptual understanding more than traditional, or what is referred to as real, experimentation. The author emphasizes that this study provides further credence to the idea that virtual/simulated laboratories can be used to provide "authentic laboratory experiences that are not substantially different to the methods employed in real science" (p. 129).

In another study examining student perceptions and learning, Somenarain, Akkaraju and Gharbaran (2010) compared asynchronous and synchronous online learning environments in a medical terminology biology course. Three formats were used, an asynchronous online section, a synchronous online section, and a traditional section, with approximately 39 students in each section. A ten-question survey was used to assess student perceptions, and the final grade for each student was used to assess student achievement. Based on survey responses, the authors found no significant difference in student satisfaction in both online groups, and overall, students reported a very positive feeling about their experience. In addition, there was no significant difference in course grades among the three groups. The authors believe that their results support the existing body of evidence in favor of online learning. Although the sample size of each group was relatively small, the results were statistically significant. A major limitation of this study, however, is that each course section was designed and taught by a different instructor, and therefore the breadth and depth of course topics may have varied significantly among the sections, resulting in dissimilar course content coverage. In addition, a pre-/post-test research design was not used and therefore they were unable to assess gains in student learning. Although this study involved a non-lab biology course, it provides further evidence that distance education via an online format provides a quality learning experience in biology courses.

In a 2011 study, Flowers explored student perceptions regarding the ability of virtual labs to effectively teach biology and laboratory procedures. He found that virtual labs can enhance understanding of the material and improve problem-solving skills. In this study, 19 non-science major students participated in a traditional biology course involving face-to-face laboratories, followed by completion of virtual laboratories. A survey was used to determine the extent to which participation in virtual laboratories had an effect on understanding biological concepts, procedures, and how to use equipment. Data indicated that the students believed that they generally learned more biology concepts participating in the virtual labs compared to the traditional labs. However, students did not find the virtual labs as effective at teaching them how to correctly operate biology laboratory equipment. A majority of students also indicated that they preferred to participate in the virtual labs compared to traditional labs. A major limitation of this study involves the small sample size (only 19 participants). Also, although this was a non-science majors' course, a pre-assessment was not given to determine prior familiarity with laboratory procedures. Finally, the results of content and procedural tests to assess student learning were not included, and instead only a survey was used to collect data to identify students' perceptions regarding key learning outcomes.

Over the course of 6-years, Gonzalez (2014) compared student learning in a biology course using three different instructional methods, each differing in terms of presentation and contact time with students. The three sections consisted of traditional lecture sections, blended sections (lab and lecture were integrated, mini-lectures are followed by problem solving and lab activities), and hybrid sections (lectures were conducted online and the lab was held on-campus). In total, 670 students were involved in the study. The lecture notes, content, and assessments were the same in all three modalities, with the addition of professor-produced video clips in the hybrid sections. Grades were primarily based on four proctored exams, which also included information about the laboratory portion of the course. Students were most successful (earned a grade of C or higher) in the blended sections and hybrid sections, and least successful in the traditional sections. However, final grades are the only means of measurement in this study, and no statistical analysis is provided to determine if the results are significant. In addition, there was a lack of randomization due to participant self-selection into specific course sections.

In addition to physics and biology, the efficacy of virtual/simulated labs has been researched in chemistry courses. In their review of virtual laboratory applications in chemistry education, Tatli and Ayas (2010) found that the results of the majority of studies they reviewed supported virtual labs in engaging students and enhancing learning. They reported that students who participated in virtual learning applications were better at describing and reporting the experimental process compared to control groups that participated in physical labs. In addition, the authors reported that students who conducted virtual labs were better able to focus on the experimental process rather than the equipment and tools, thereby narrowing their focus of attention while also enjoying the experience. The authors support the use of virtual laboratories as supportive tools when a physical lab is insufficient or unavailable, however they suggest incorporating technology that simulates the real lab experience as closely as possible.

Hawkins and Phelps (2013) randomly assigned chemistry students to either an experimental or control group, and used pre- and post-tests to assess conceptual and factual understanding. They found that general chemistry students in virtual and hands-on learning environments performed similarly well on portions of exams that were hands-on, but virtual students were more likely to use specific laboratory techniques and were less likely to make mistakes with the equipment. Josephsen and Kristensen (2006) incorporated simulated labs into an introductory organic chemistry course to determine their effect on learning and interpretation of experimental results. The simulated labs were used to supplement what the authors refer to as real laboratory experiences, with approximately equal time split between the simulated and hands-on activities. After using the simulated lab programs, students completed an attitude survey evaluating the lab, and a pre-/post-test research design was used to assess gains in knowledge. Students responded favorably to the simulated labs. Like Hawkins and Phelps (2013), the authors conclude that working with the simulated lab technology was an asset to the lab experience and may be a valuable teaching tool to engage students, as well as to facilitate their learning process. However, this study did not include a control group to compare differences in learning. In addition, no statistical analyses are included in the paper, including score gains on post-tests. In accordance with previous research that emphasizes the necessity of realistic simulations to generate an authentic lab experience (e.g., Sauter et al., 2013; Zumbach, Schmitt, Reimann & Starkloff, 2006), Josephsen and Kristensen attributed the students' positive attitudes regarding the simulated labs to the authenticity of the labs, asserting that the simulation program should closely simulate the actual laboratory procedures. This is concomitant with earlier studies that positively correlated the effectiveness of lab work with its link to the real world (e.g., Cooper et al., 2002).

Online/Virtual Applications in Anatomy and Physiology

Despite the growing body of literature regarding supplementation and enhancement via virtual/online components in science disciplines including physics, chemistry, and non-science majors' biology, substantial empirical evidence regarding the efficacy of fully-online courses in delivering content in higher education lab-based science majors' courses is lacking, especially in anatomy and physiology. Anatomy and physiology is a science whose instruction relies on demonstrations and laboratories to reinforce course material (Dwyer, Fleming, Randall & Coleman, 1997). Anatomy and physiology courses, by nature of the subject matter, technical terminology, and volume of content, are considered the most challenging courses among biology majors and health-service students. As such, it is not surprising that students often intuitively fear the subject and are more likely to report that they are dissatisfied with the instruction and feel overwhelmed (El-Sayed et al., 2012; Johnston, 2010). Therefore this subject requires implementation of "innovative approaches" when possible (White & Sykes, 2012, p. 2), and teaching techniques that make the material more tolerable and comprehensible for students. Although the research is limited, the data that exist for online, hybrid, and web-enhanced anatomy and physiology courses appear promising. Most studies in this arena indicate that students who are exposed to a technology-mediated component performed as well as or better than their face-to-face counterparts. Technology-enhanced teaching, including virtual/online strategies in fields associated with health and science, including anatomy and physiology, has been demonstrated to have a positive influence on learning.

In a systematic review of the literature aimed at evaluating the effectiveness of online learning for undergraduate health profession education, commissioned by the World Health Organization Department of Health Workforce, in collaboration with the Department of Knowledge, Ethics, and Research, researchers found online and e-learning to be as effective with regards to knowledge and skill acquisition as traditional methods for training health care professionals (Al-Shorbaji, Atun, Car, Majeed & Wheeler, 2015). Anatomy and physiology, a requisite for most health care programs, has been examined, however not extensively. Raynor and Igguldent (2007) identify the different levels of background knowledge anatomy and physiology students have at the beginning of the course as one of the largest promoters of anxiety among students. Without appropriate strategies to normalize the differences and prepare students, such as online interactive resources, students will continue to view these courses as “very difficult” (p. 99).

The studies conducted on physiology laboratory simulations have found that they have substantial educational value and are well received by students, thus they can be a practical and effective alternative to traditional lab experiences. Dobson (2009) investigated the effectiveness of simulated laboratory activities in a physiology course compared to traditional hands-on activities. The author created a virtual lab program that consisted of four modules dealing with physiology. A total of 25 students from an integrated fitness programming course served as the research population. After student participants were categorized by their major, concentration, and course history experience, they were randomly assigned to one of two experimental groups, although the researchers took measures to ensure they were divided as evenly as possible by background. Experimental group one completed a hands-on version of an oxygen consumption module while group two completed the virtual laboratory module. Each group then completed the same 30-question assessment to determine what they had learned from the activities. The groups then switched roles for a second module on lactate and ventilatory threshold, group one completing the virtual module and group two completing the hands-on version. Again, both groups completed the same post-assessment. An analysis of the assessment data indicated no statistical difference in learning between the two groups when the means were compared. The simulated lab students performed equally as well on summative assessments as the hands-on lab students. The author concludes that the results of this investigation concur with previous studies demonstrating the effectiveness of laboratory simulations, however, a number of limitations exist for this research study. The research population and group sizes were especially small and do not represent large enough populations to draw valid conclusions. For a research population of this size, ANOVA may not be an appropriate test of statistical significance, as a sample this size reduces the power of the test (Dattalo, 2008). No pre-tests were conducted to determine students' understanding of the concepts before the activities - this is especially important when comparing student understanding of concepts. Finally, the researcher did not describe how the post-test questions were developed, whether they were previously field-tested, or if they established reliability or validity for the questions.

White and Sykes (2012) evaluated a blended (hybrid) approach for an anatomy and physiology module. Instead of traditional content delivery using lectures and models, a module was adapted to encompass both a face-to-face portion and an online component. The online module was delivered in four sections in four separate semesters and compared to traditionally-taught control groups. Student performance was measured by outcomes in two computer-based summative assessments - a multiple choice exam and an exam with varying question formats. Student perceptions were measured using an end-of-semester online student evaluation system. The authors found that post-test scores of student groups who received computer-enhanced delivery in the anatomy and physiology module were higher than those who received the same content by lecture alone, indicating "a higher level of cognition was achieved" (p. 5). The authors stress that their results contradict previous research that concluded that traditional methods achieve better performance in multiple-choice examinations when compared with online students (e.g., Reime, Harris, Aksnes & Mikkelsen, 2008). This study was limited in scope, as only one module in a course was tested, and there were a limited number of participants. In addition, a pre-/post-test design would have strengthened the conclusions drawn from this research by allowing comparison of gains in student learning.

El-Sayed, El-Sayed, El-Hoseiny, and El-Raouf (2012) investigated the effect of exposing students to computer-assisted learning in the form of video-based teaching material in a human anatomy and physiology class. They hypothesized that the use of computer-assisted multi-media software, such as video resources, would enhance knowledge acquisition and increase the quantity and quality of time on task. A quasi-experimental design was used, in which the treatment was alternated between the groups, but for different topics – ten topics in total, with five topics randomly selected as video-taught for half of the students and lecture-taught for the other group, allowing examination of the effectiveness of multiple treatments within the same intervention condition. Knowledge acquisition was measured by quizzes composed of questions that reflected the learning objectives of each lecture. Student satisfaction was measured using a Likert scale to indicate agreement or disagreement with scale items. A weakness of this study is that the small sample size (N=27) limits the conclusions that can be drawn, however the data indicate that video-based lectures were associated with higher achievement on exams than the traditional lecture method, and may actually be slightly more effective. Students reported that the use of videos improved their understanding of course topics and had a positive impact on their motivation. In addition to the small sample size that limits the statistical conclusions drawn, another limitation of this research is that a pre-/post-test design was not utilized, and instead only post-lecture quizzes, a midterm, and a final exam were used to determine gain in knowledge.

One of the caveats of asynchronous online courses and virtual labs is the flexibility and availability of resources. The degree to which students actually exploit the availability of online resources in an online class has been explored in anatomy and physiology classes. Like El-Sayed et al. (2012), Guy, Byrne, and Rich (2014) also investigated the use of videos in anatomy and physiology classes. However, their study did not focus on student learning, and instead focused on student use of anatomy and physiology online resources – how often they were utilized and student perceptions of the resources. Student survey results indicated that a majority of the students utilized the video clips, and their responses indicated that they felt the video clips enhanced their learning. In this study, no learning assessments were used to directly measure the effectiveness of the resources or the extent to which they enhanced learning. Although it was not the direct focus of the research, this study could have been strengthened by correlating the quantity of resource use (and perhaps breadth and depth of content in the resources most-often utilized) with overall scores in the course. In a similar study comparing use of online resources, Green, Weaver, Voegeli, Fitzsimmons, Knowles, Harrison & Shephard (2006) used Blackboard to post resources aimed at supporting anatomy and physiology students as part of blended instruction. Biological systems were addressed in lecture, and resources for each system appeared in Blackboard according to the lecture timetable. The online resources included text readings, notes/lectures, tutorials, videos, assessment questions, and online discussions. In total, the resource usage was monitored for 652 students, and 72 students completed a questionnaire regarding their learning experience. Although a majority of students utilized the virtual learning resources and responded favorably regarding the types of resources available, their frequency of use did not correlate with their final grade in the course, which may reflect the fact that the virtual content was not mandatory and students had access to the content and instructor in the classroom. The authors conclude that the use of a virtual learning environment supported student learning in anatomy and physiology and appeared to contribute to a good overall learning experience for the students. This represents an exploratory and descriptive study to evaluate the use of a virtual learning environment, as there was no true research design implemented.

Abdullahi (2011) looked at student exam participation and performance in an anatomy and physiology II class. Four web-enhanced traditional sections and four online distance hybrid classes were used for the study. The web-enhanced classes were conducted in a face-to-face format for regular lecture and labs, however supplemental notes were provided online. The hybrid classes only met for laboratory sessions, and the rest of the class was conducted online. Students in each group were compared to determine if hybrid students take advantage of the flexible nature of distance learning, including convenient exam scheduling and multiple exam attempts. No significant difference was found when comparing grades from a single-attempt proctored comprehensive final exam given at the end of the course. No significant differences in exam preparation or grade distribution between hybrid students and traditional students were found, despite the fact that hybrid students had a maximum of three exam attempts. Although the hybrid students were less likely to complete the course and had higher withdrawal rates, the traditional students had higher failure rates. A limitation of this non-randomized study is the small sample size (N<45 participants in each group). Although it is indicated that the same exam format was used, it is unclear if the hybrid students and web-enhanced traditional students were given the same exams, if a pre-test was utilized at the start of the course, or if student demographics differed in each group.

Raynor and Igguldent (2007) explored the effects of using computer-assisted learning materials in an anatomy and physiology course, specifically an electronic book (e-book) that includes functional enhancements meant to enrich the reader’s experience. Such functionalities include note-taking, multimedia interactions (animations and video clips), 3-D images, online dictionary access, a keyword search function, and interactive graphs and tables linked to data in the book. Their aim was to evaluate how effective the online e-book resources were in supplementing face-to-face anatomy and physiology learning and teaching. The researchers implemented an e-book in two groups, one group consisting of 135 pre-registration Bachelor's nursing students and the other group consisting of 25 post-registration Master's nursing students. The groups utilized the e-book over the course of two semesters, and a questionnaire was used to gather data at the end of each semester. The results of the study "strongly suggest" that an interactive e-book is an effective online supplement to traditional face-to-face anatomy instruction (p. 103). However, student satisfaction with the e-book was highest in the post-registration group, which the authors believe may indicate that those with a stronger background would benefit more from this resource. The authors state that "the quantitative data…[indicate] this resource as a potential replacement for print"(p. 103). A major limitation of this study is the lack of control group to compare learning. Although the authors state that the aim of the research was to evaluate the effectiveness of using an online resource, no learning assessments were included in the research design and student success rates were not reported. The only support included for the conclusions are the percentages of students from each group who responded that they had a desire to continue using the e-book as a course resource. Despite the lack of actual assessment and data analysis, the qualitative data the authors collected is useful for determining what e-book features students find most effective to enhance learning.

In a 2010 study, Gopal, Herron, Mohn, Hatsell, Jawor, and Blickenstaff investigated how online interactive tools can be used to supplant teaching an undergraduate anatomy and physiology cardiovascular system laboratory module. The study involved 165 students, divided into control and experimental groups. The students in the experimental group had access to a website that included audio pronunciation guides, practice and self-test identification activities, videos, and games. Scores from lab tests were compared, and it was found that students demonstrated a significant improvement in their performance and “took advantage and benefited from the technology tools provided” (p. 509).

The emergence of online/virtual learning in contemporary education has not been without criticism. Despite results from the research that has been conducted, the efficacy of the nontraditional online course modality to support student learning is questioned by some academic leaders (Allen & Seamen, 2013). Acceptance of online courses as credible and quality equivalents to regular face-to-face courses is mixed, and this type of teaching domain has its detractors. The use of virtual/online science courses and their associated labs seem to only be accepted by a majority of science educators when a “real” laboratory is not possible, either because of temporal or spatial dimensions, budgetary constraints, or when an intolerable level of danger is present (Zacharia, 2006). The impact that the learning environment has on learning outcomes has been explored; however there has not been significant focus in certain areas of biology. Such research is necessary to support online biology course initiatives, and exploit the potential advantages they offer. There exists a significant need for empirical evidence demonstrating that fully-online post-secondary biology majors’ learning experiences are equivalent to traditional on-campus experiences insofar as achieving the same goals and learning outcomes with regards to understanding the content and acquiring procedural skills.

In an exclusively online course, assessments are administered through the course learning platform or some other distance method. Thus, it is important that the use of technology be explored with regards to assessment procedures. Maza (2010) investigated the use of a virtual reality application in a veterinary gross anatomy class. Examination scores of two groups were compared – one group completed examinations in a traditional in-class format (physically handling specimens) and another group completed examinations on specimens in a simulated three-dimensional QuickTime movie module. Students were randomly assigned into one of two groups for each of the four assessments in the course. No significant differences were found between the two sample means for each exam; thus the author concluded that the quality of specimens viewed using either method is the same and similarly effective for the study population. Therefore, using computer-based three-dimensional movie software for assessment purposes may be an "acceptable alternative…for testing gross anatomy knowledge and comprehension" (n.p.) - akin to conclusions made by others with regards to software applications in anatomy courses (e.g., Biasutto, Caussa & Criado del Rio, 2006). However, conclusions from this study must be viewed with caution, as a small sample size was used (N=26) and therefore ANOVA may not be an appropriate test of statistical significance.

Advantages and Disadvantages of Online Science Courses

Offering more science courses online/virtually will allow institutions to reach large numbers of students who are geographically dispersed, which may influence interest and enrollment in STEM programs, thereby increasing the pool of potential students. In the past, physical and logistical challenges hindered the use of computer-assisted learning, particularly in a laboratory setting (Dwyer et al., 1997). However, technological advances have broadened the reach of online courses to a more general student audience, and software technology has dramatically increased the quality and applicability of virtual media. Various studies outline additional advantages of incorporating online/virtual elements to science courses.

Swan and O'Donnell (2009) stress the benefits of incorporating technological media into science college courses, especially for first-year science students in academically-demanding large enrollment courses. In these courses, students can maintain a level of anonymity and isolation due to the large class sizes, and they may also lack skills necessary to effectively seek help when they are struggling. Research demonstrates that students in high-enrollment lecture courses often do not retain information or develop higher-order thinking skills (Riffell & Sibley, 2005). This is especially problematic if the students are underprepared to begin with. Swan and O'Donnell (2009) emphasize that participation in online discussions and online review assignments can help students engage with the material, since they have unrestricted access to course materials and exercises. In addition, students are able to exert more self-control regarding when and where they submit assignments, as well as where and how they learn.

Some scientific principles and abstract theoretical concepts are difficult to explain and demonstrate in a traditional lecture setting (Dwyer et al., 1997). Understanding physiological concepts cannot be done by simply committing a list of facts to memory, and instead involves simultaneous comprehension of dynamic and complex interactions among processes that provide integrative control and regulation over body function. The research conducted thus far supports the conclusion that this problem can be overcome by virtual and digital simulations and animations. Hwang and Esquembre (2003) stress that technology-mediated simulations can help students "understand invisible conceptual worlds of science through animation, which can lead to more abstract understanding of scientific concepts" (n.p.). Black (2002) echoes this sentiment, and emphasizes the importance of animations in certain learning circumstances, stating that "a picture may [be] worth a thousand words and animation may be worth a million" (n.p.). Virtual laboratory environments can provide students with the option of repeating data manipulation and interpretation techniques that the standard three-hour period of the conventional laboratory does not allow (Raineri, 2001), as well as allow unique interactions with data that provide opportunities to examine patterns that might otherwise be impossible in a physical laboratory session (Singer & Bonvillain, 2013).

In an online environment, virtual labs allow students repeated access to animations, simulations, and videos, unlike traditional labs whereby students typically get one opportunity to perform the procedure. Their inherent flexibility means that students can manipulate data, perform experiments multiple times, and pause the simulation allowing time to fully understand the process before they move on. Finkelstein et al. (2005) describe simulation labs as "more productive" than real equipment in accomplishing certain goals, including increasing time spent on task. Varying experimental procedures and variables outside of the prescribed methodical investigation (or what Finkelstein et al., 2005, characterize as "messing about," p. 6) is beneficial to learning the process of science, understanding scientific inquiry, and may help students acquire more sophisticated procedural skills. However, such activities may only be productive under certain constraints. User-friendly software and computer media can lead to active participation and be programmed to constrain students in more "productive" ways, such as regulating device output and settings to decrease human error, thereby limiting activities to those that are generally on task or supportive to the goals of the laboratory. This can be accomplished while also conserving time in the classroom.

Hallgren et al. (2002) compared mid-term and final grades of two groups of first-year medical students enrolled in a gross anatomy laboratory – a group that had access to web-based self-assessment exercises and a group that did not. The web-based resources included anatomical landmark reinforcement drills that provided immediate feedback to students. The authors found that students who had access to the online resources scored significantly better on exams. The authors attribute students' improved recall and recognition abilities to their use of the online materials, and they suggest that incorporating online drills and activities and expanded research in this area "…would be of benefit and interest to medical educators and students alike" (p. 265). Learning in an online/virtual environment can be more-student centered versus the traditionally passive science lecture setting (Riffell & Sibley, 2004). Reuter (2009) suggests that the dynamics of on-campus labs may actually hinder student learning. Collaborative group learning is often encouraged in educational settings, especially in a traditional laboratory environment whereby group work is the norm, but individual competency is the intent. The author describes a science laboratory environment as a "prime example of collaborative learning" (p. 160), however states that such environments may allow a student to successfully complete a lab, despite not having developed the skills or acquired the knowledge to solve the same problem independently at a later time. Online students are not afforded this collaborative advantage and therefore are required to learn, assimilate, and apply the concepts from the lab, resulting in increased individual learning. This, the author suggests, may be one of the reasons why online lab learners outperform on-campus synchronous lab learners.

Online environments allow customization of dynamic labs that allow students to take advantage of the technology for measurements and calculations, which allows students to alter variables, and focus on critical thinking and data analysis. In anatomy and physiology, this means that computer software can visually illustrate mathematical relationships of physiological concepts, something that is difficult to replicate in a lecture setting. Access to real scientific experimental devices and equipment may not always be available, and therefore technology-mediated labs allow otherwise inaccessible labs to be conducted, even on limited school budgets. Economic issues make it difficult for financially-strapped institutions to maintain expensive chemicals and apparatus in traditional laboratories (Ma & Nickerson, 2006) as well as supply increasingly expensive animal specimens (Dwyer et al., 1997). These budgetary constraints and lack of general resources and facilities can severely restrict the types of labs that are performed in science classes, making some labs that involve such chemicals, specimens, and equipment prohibitively expensive.

Some experiments and procedures may involve chemicals and equipment that can be dangerous to use, store, and maintain (Nedic, Machotka & Nafalski, 2003). In addition, technical and time-consuming experiments and procedures can place a burden on the lab instructor, and make it difficult to provide the appropriate level of vigilance to each lab group, and can hinder checking progress and answering questions, especially in large and over-crowded labs. Becoming proficient in scientific procedures and knowing the function of common laboratory equipment is critically important and pivotal for preparing competent scientists. The ubiquity of computers in higher education and access to simulated/virtual labs that imitate or mimic traditional labs can be a safe and cost effective alternative to teach specialized skills while reducing overall costs and enriching the educational experience (Ma & Nickerson, 2006).

Teaching science and procedural skills is largely dependent on the school's abilities to provide an "adequate scientific environment" (Zumbach et al., 2006, p. 285). The infrastructure of some facilities does not accommodate ideal conditions for learning specific content/procedures using hands-on labs that demand a lot of space. Dissection of cadavers is likely considered the ideal hands-on strategy for learning human anatomy; however, their availability is limited, and there are many regulations that can proscribe their widespread use, in addition to laws in some countries that prohibit their use in higher education institutions. Virtual cadaver or animal dissections could be used to enhance or replace the cat and pig dissections that are commonly used in anatomy and physiology courses. Research regarding technology-assisted learning in anatomy courses has identified numerous benefits to its use (e.g., Brenton, Bello, Strutton, Purkayastha, Firth & Darzi, 2007; Murgitroyd, Madurska, Gonzalez & Watson, 2015).

Animal dissection simulations and synthetic specimens provide alternatives for students who have physical limitations or special needs (Scanlon, Colwell, Cooper & DiPaulo, 2004), or moral objections to traditional specimen dissections. It has been questioned whether educators, in this day and age, where technological surrogates are available, should be "killing animals to help young people learn about the internal structure of animals" (de Villiers & Monk, 2005, p. 583). (For review, see Akpan, 2001). Sugand, Abrahams, and Khurana (2010) report that many undergraduate institutions now deem conventional cadaver dissection as obsolete, and instead report that anatomy education is being revolutionized with greater reliance on high-tech imaging software and models. This is especially important to cogitate in light of the fact that there is debate in the literature regarding whether cadaver dissection is the best teaching method when compared to some technology-driven alternatives (Sugand et al., 2010). In addition, it is important to determine if risks associated with exposure to chemicals and preservatives outweigh the learning benefits of a hands-on lab experience (Miller, Perrotti, Silverthorn, Dalley & Rarey, 2002). As the role of dissection, especially of mammals, in biology education continues to be debated, alternatives to formal dissections have been explored, many with success in regards to achievement of learning objectives (e.g., Dewhurst, Hardcastle, Hardcastle & Stuart, 1994; Greenfield, Johnson, Shaeffer & Hungerford, 1995). Presumably, the satisfaction reported when using alternatives among students is partly due to the ability to move at a more individual pace, which can reduce frustration and confusion, and the personal satisfaction of not having contributed to the death of an animal if alternatives are available.

There are perceived disadvantages to performing traditional in-class biology experiments. Lunsford (2003) compared the process used in many traditional biology experiments to a following a cake recipe, suggesting the procedures do not stimulate creativity and independent thinking. Swan and O'Donnell (2009) view the truncated scheduling and time constraints as a disadvantage of traditional courses and labs, arguing that time boundaries can limit and potentially deny students the opportunity to review and rehearse the procedures or repeat them if necessary. Meyer (2003) emphasizes the importance of class time, describing it as a "resource," and asserts that online course components can allow more time for reflection and for focusing on course objectives beyond the constraints of face-to-face course scheduling (p. 56).

Kennepohl et al. (2005) place the laboratory component at the "heart" of science courses (n.p.). Traditional hands-on laboratory activities have "set the standard for quality laboratory experiences against which virtual laboratory programs must be compared" (Dobson, 2009, p. 342) and have long played a vital role in educating students about the process of science. In contrast to those who cite the advantages of online/virtual labs, critics of fully-online lab experiences as an alternative, supplement, or replacement for traditional hands-on lab experiences have argued that such labs have drawbacks. Many online critics lament at the thought of losing face-to-face interactions. Online science courses can eliminate face-time with instructors and may reduce critical peer interactions and collaborations, structure, and real lab experiences that include kinesthetic experiences such as feeling, touching, and smelling - thereby promoting a "disconnect between real and virtual worlds" (Magin & Kanapathipillai, 2000, p. 6). Consequently, it is argued, they cannot be as effective as or equivalent to traditional wet labs. Thus, the assertion is that students can only properly learn by performing an experiment or dissecting a specimen within a classroom or laboratory setting and that virtual/simulated lab courses deny students a real lab experience.

Conventional hands-on laboratory experiences are routinely referred to as "real labs" in the literature (especially articles published before 2006), and have been described as "without a doubt….irreplaceable" (Nedic et al., 2003, p. 6). Even some proponents of virtual/online labs hesitate to fully accept and embrace the empirical evidence of their utility. Despite using virtual lab simulations and conducting research that demonstrated their educational value and impact on learning outcomes, Raineri (2001) states that "nothing can or should be used to replace the traditional hands-on approach to learning experimental techniques" (p. 162). MacQueen and Thomas (2009), although proponents of online science courses, state that "nothing can truly substitute for the tactile experience of getting one's hands dirty in the laboratory or field" (p. 142). This sentiment is echoed by others, including Biasutto et al. (2006), who believe technology can be used to complement anatomy laboratories, but should not be used to replace direct contact with specimens. Pawlina and Lachman (2004) emphasize that teaching anatomy in the absence of dissection provides students with an "artificially narrow experience" (n.p). Virtual dissections and synthetic specimens may be more likely to present idealized versions of organisms and structures, and therefore may not account for natural anatomical or developmental variations among 3-dimensional specimens of the same species. Such inherent variations encountered during a hands-on dissection may provide students with a better understanding and appreciation of form and function and the interconnections of organs and organ systems. Some companies are recognizing the importance of anatomical variation and to address this concern, now include comparative analysis and rare pathology examples (such as Anatomage Medical).

Gallick (1998) commented on the institutional effects that could occur as a result of the influx of online courses being offered at more and more institutions. The author cautions that fully online classrooms may result in total replacement of the faculty member by pre-recorded lectures and software, resulting in opportunities for cost-saving measures that will decrease the number of full-time faculty members and increase the number of part-time and non-tenure track instructors and TAs who teach and monitor the courses. The author believes that the main concern will be issues of quality control. Gallick also suggests that accreditation standards may become more lax as universities adopt a more online student-centered approach to education and rely less and less on full time tenure-track faculty and maintaining a physical campus, which serve as the resource for content. Such measures portend to commercialize education, and may taint the prestige of a college education and devalue university degrees. Such threats can be minimized if "quality and thoroughness of the design and delivery" are considered as the primary catalyst when developing online courses (Aragon, Johnson & Shaik, 2000, p. 22).

Some researchers have found virtual labs to be less effective at promoting student learning than traditional lab experiences. Stuckey-Mickell and Stuckey-Danner (2007) investigated student perceptions of virtual biology lab exercises used in post-secondary online human biology courses. Students completed both hands-on and virtual labs to compare their experiences as well as examine the effectiveness of these labs. In total, students participated in 22 lab experiences – 12 hands-on labs consisting of viewing models, labeling images, and data-collection, and 10 virtual laboratories involving "pointing and clicking to manipulate virtual lab equipment" (p. 107). With the exception of comparison wet lab components, the courses were conducted completely online. The authors collected data regarding perceptions from 38 students, and although students indicated that the traditional face-to-face labs were more effective, students responded that the virtual lab experiences enhanced their understanding of course content. The authors acknowledge that the virtual and traditional labs addressed different concepts and were not direct comparisons, however they emphasize that the same procedures were followed in each experimental condition. A major limitation of this study is that student understanding was not assessed, only self-reported student perceptions on a Likert-scale. Although this study found that virtual labs were not preferred by students over face-to-face labs, most research on virtual lab effectiveness has been positive, and many studies that involve integration of a virtual component, outlined in this section, have demonstrated that such virtual/computer-based simulations enhance student outcomes.

Daymont and Blau (2008) attribute general and persistent negative perceptions of online courses to the fact that these courses were initially offered pervasively at for-profit, less prestigious institutions. In the last decade, community colleges have become forerunners of online learning opportunities, however other higher education institutions are quickly following suit. Presently, online course offerings are steadily on the rise among virtually all tiers of higher education institutions: two-year, four-year, state, and private, including prestigious Ivy League schools. Despite their ubiquity across the gamut of higher education institutions, using technology to deliver course content in an online medium is still met with skepticism, and this is especially true in regards to science.

There is only a small body of literature regarding differences in learning in online versus traditional laboratories. Although most of the research sheds a positive light on learning science in an online modality, some professional and educational organizations and societies dismiss or reject the potential value of virtual labs, including virtual dissections. For example, *The National Association of Biology Teachers* (NABT), in their Position Statement regarding the use of animals in biology education (adopted in 2008), urges teachers to be aware that "alternatives to [hands-on specimen] dissection have their limitations… and NABT supports the use of alternative materials as adjuncts to the educational process but not as exclusive replacements for the use of actual organisms." If this position is based on empirical evidence and facts, then online/virtual lab courses deprive students of the experiences they need to develop practical skills to become true biologists. This can be especially significant because improper laboratory techniques and experimentation procedures may be easier for instructors to identify in a face-to-face environment and therefore may persist longer in a distance learning setting (MacQueen & Thomas, 2009). Although Al-Shorbaji et al. (2015) found online courses effective for teaching proper skills in health care professionals; longitudinal studies correlating practical laboratory techniques with learning modality have not been conducted. Other organizations, including the *Human Anatomy & Physiology Society*, support "distributed learning" – those methods that use a range of technologies to provide learning opportunities over distance and time, which includes "entirely online courses using various technologies to achieve the course objectives" (HAPS Distributed Learning Position Statement, 2011). Similarly, in their Position Statement on E-Learning in Science Education (adopted in 2008), the *National Science Teachers Association* (NSTA) "supports and encourages the use of E-Learning experiences in preK-16 science students…" (p. 1), including virtual courses, which they describe as a "viable and effective models for teaching important science content and meeting diverse student needs" (p. 3) and state that such courses can "significantly enhance teaching and learning" (p.1).

Of course, by virtue of the course modalities themselves, the experiences students have in online/virtual lab courses compared to traditional, synchronous, hands-on lab courses cannot be equivalent in all aspects, *but do they accomplish the same goal(s) in regards to conceptual* *learning and content assimilation*? This is especially important to consider from a pedagogical dimension, given that lab-based courses maintain such a critical role in science education. Studies have demonstrated that online science courses, or science courses that employ a virtual technology component, such as a simulated laboratory activity to augment existing course assignments, have educational value, and in some cases exceed that of conventional face-to-face hands-on laboratory experiences. In addition, research indicates that virtual labs are generally well received and perceived by students. In fact, as outlined in this section, much of the scholarly literature indicates that virtual activities are often preferred over traditional face-to-face experiences and their use can make positive contributions to learning objectives. Even so, there is still unresolved debate regarding the effectiveness of using simulated/virtual technologies in science classes. In their meta-analysis of the effectiveness of simulated and remote labs, Ma and Nickerson (2006) describe ardent adherents of hands-on laboratories as “ignoring evidence” that demonstrates the effectiveness of simulated and remote laboratories (p. 10). Interestingly, it appears as though attitudes regarding superior pedagogical methodologies tend to be dominated by tradition rather than empirical evidence.

Larson and Sung (2009) offer perceptive insight as to why the “traditional mode of education delivery” (face-to-face) is so ubiquitous and so widely accepted and embraced – because years ago there was *no* alternative. Before the advent of computer software and other multimedia technology, face-to-face instruction was all that was available. They perspicaciously conclude that “we…do not have to hold on to something that existed because it was our only option. It exists not because it has to, but it exists because it was the only option” (p. 41). Historically, dissection and pedantic lectures were not only standard practice, but essentially the *only* pedagogy (Sugand et al., 2010). Instead of discounting evidence, the ultimate goal of scientific educators should be to take advantage of the potentials of the instructional tools and pedagogical methods available to maximize and optimize the degree of effectiveness (Zacharia, 2006). Moreover, it is important to note that hands-on laboratories are using computer-mediated technology to control equipment and perform data analysis more and more (Ma & Nickerson, 2006), and therefore such hands-on labs "already involve… computer-mediated and simulated tools" (p. 10). It can then be argued that there is rarely a pure hands-on experience for students, and instead references made to labs in general are describing "relative degrees of hands-on, simulation, and remoteness" (p. 14).

Educators should not look to technology-based virtual learning environments as a panacea for education. Instead, educators should identify where and when virtual learning environments can and should be used as a vehicle to facilitate learning and promote sound pedagogical practices. This is true for all disciplines, including the natural sciences. It is imperative that the controversy over the effectiveness and utility of virtual/online lab-based science courses be abated, as this information is critical for administrators and educators to make decisions that will fully exploit the advantages of incorporating virtual technologies – as such decisions should be made with sound and evidence-based underpinnings. More research on fully-online post-secondary lab-based science majors' courses that utilize current technologies is necessary to fully ascertain their efficacy in helping students master learning outcomes in the natural sciences.

CHAPTER 3: METHODS AND PROCEDURES

Overview

This chapter begins with a description of the research site, courses used in the study, and the participants involved in the study. A detailed description of the recruitment procedures is provided. The development of the instrument used in this study to assess gains in conceptual knowledge (pre- and post-tests) is described, as well as the procedure of administration. This chapter concludes with a review of the data analytic procedures.

Research Site

All data collection was conducted at a community college located in New York State. One of 64 SUNY institutions, it is a two-year liberal arts college that offers broad-based career and transfer-oriented curricula on a degree or certificate basis. During the time of this study, the total number of students attending the institution was over 4000, with approximately half matriculated as full-time, approximately 65% female, approximately 80% white, and a median age of 23 years (2014-2015 College Catalog).

Course Descriptions

Anatomy and Physiology I is the first four-credit lab-based course in an anatomy and physiology sequence, and serves as a prerequisite for the second course in the sequence. Units within this course include cells, tissues, integumentary system, skeletal system, muscular system, nervous system, and special and somatic senses. Anatomy and Physiology II is the second four-credit lab-based course in an anatomy and physiology sequence. Units within this course include digestive system, endocrine system, cardiovascular system, respiratory system, lymphatic system, immune system, urinary system, reproductive system, and water/electrolyte/acid/base regulation. Each course has a departmental master syllabus that prescribes the specific course content and dictates student learning outcomes for every instructor in every section. The master syllabi were developed by full-time biology faculty with competency in the subject matter, and are continually updated and revised on a semi-yearly basis. Each course contains 11 content-specific learning outcomes. These outcomes were updated in 2011 and were crafted to be measurable via course-based assessment.

Anatomy and Physiology I and II serve as mandatory requisites and foundation courses for the school's Applied Science Health Concentrations - including nursing, medical imaging, respiratory therapy, radiation therapy, medical technology, physical therapy, chiropractic medicine, and cardiovascular perfusion. Articulation agreements with various schools in New York have been established, and a grade of C or better guarantees the anatomy and physiology credits will transfer upon acceptance into related Health Science Programs at schools where the agreements are in place. In addition, these courses are routinely populated by physical education, occupational therapy, exercise science, and registered nursing students at the study site as well as colleges throughout New York.

On-campus sections of anatomy and physiology are taught in a traditional face-to-face synchronous classroom environment, and consist of three hours of lecture and two hours of lab each week (Table 1). Class assessments consist of semi-timed exams (constrained by the class period), no fewer than three lecture exams, and at least two timed laboratory practicals. Laboratory activities vary depending on instructor, however all sections included in this study included a dissection component, either pigs or cats, in addition to human models, and some instructors supplemented lab activities with virtual experimentation using *PhysioEx* software

(Zao, Stabler, Smith, Lokuta & Griff, 2015). Although some instructors utilized virtual labs, these labs were conducted in a computer lab during the scheduled laboratory session, and thus no components of the on-campus courses were completed virtually off-site.

The institution where the research was conducted was one of the first SUNY colleges to offer anatomy and physiology courses in a completely online format, and has been running approximately 50 sections per year since 2007. The course was initially developed for use in Lotus Notes as the content management platform in 2002. In 2007, the school transitioned the content management platform to Angel, and then finally to Blackboard in 2014. All full-time faculty members in the Biology Department who teach these courses are regularly involved in course development, maintenance, and updating. Online course sections use the same lecture and lab materials, and the learning activities and assessments are standardized across all full-time and adjunct faculty sections. Thus, students are exposed to similar online learning experiences regardless of instructor or section for each course. In online sections, class assessments consist of nine timed exams, a timed cumulative summative assessment, and at least two timed laboratory practicals (Table 1). Lecture activities consist of assigned textbook readings, narrated lecture presentations, and multimedia activities and presentations. Laboratory activities consist of virtual human cadaver dissections and virtual experimentation using *PhysioEx* software and *MasteringAandP* activities. The same textbook is used in on-campus and online sections (Marieb and Hoehn, 2014), and each course covers the same breadth of content.

Sample and Measures

This research was conducted using a quasi-experimental control group design with nonrandom group sampling (Figure 1). The sample in this study consisted of students in undergraduate 200-level Anatomy and Physiology I and Anatomy and Physiology II courses. A convenience sample was used, as participants self-selected by virtue of their enrollment into their preferred instructional modality and registration in one or both courses, Anatomy and Physiology I and/or Anatomy and Physiology II (students at the study site are not required to demonstrate online readiness to register for online courses). Participants were sampled from courses that were taught during two semesters (fall 2014 and spring 2015). Two different course modalities were available to students for each class over the course of two semesters, fully-online asynchronous instruction and traditional face-to-face on-campus classroom instruction. As outlined in Tables 1 and 2, there were a total of 33 sections included in the study (16 online and 17 on-campus). Class capacity of online sections was 25 students per section, and of on-campus sections ranged from 24-31 students per section. In total, 966 students were enrolled in one or both classes in the 2014-2015 academic year, and a total of 698 were enrolled in class sections included in the study (Table 2). During the timeframe of data collection, the sections were taught by nine adjunct faculty members and seven full-time faculty members.

Based on a recent Diversity Report (2012) published by the college, the college demographics at the time of this study were reflective of the typical diversity of the surrounding counties. Descriptive statistics for the study population are reported in Table 3. The subjects of this study included 397 students. All course sections were dominated by females (a reported total of 340 females and 56 males). Most of the participants identified as white (356). Unlike the homogeneity observed in gender and race, the mean ages of the groups displayed more heterogeneity. Ages ranged from 18-57, with the average age being 26 years (the mean age was 24 years in on-campus sections and 29 years in online sections). Most participants (358) were using the course(s) as a prerequisite for admittance to a health science program or a nursing program. Among the 397 participants, 179 took the course in an online delivery format and 218 took the course in a traditional classroom format. Regarding the participants' learning experiences, 62% reported having prior experience using Blackboard, and 38% responded that they had no prior Blackboard online experience.

In order to determine an appropriate sample size for this study, a power analysis was conducted using G*Power (Faul & Erdfelder, 1992) with power (1-β) set at 0.80 and α at 0.05, two-tailed. Additionally, "known" and "expected" means were drawn from previous semester student scores (A&PI). This analysis showed that a sample size of 201 ($N=201$) would be sufficient to detect group differences at the $\alpha = 0.05$ level.

As this study relied on the cooperation of various instructors, some sections offered during the academic term of the research were omitted from the study due to instructor noncompliance. Average response rates for non-incentivized education surveys administered in online and paper formats are approximately 33% and 56% respectively (Nulty, 2008). In order to establish the best representation of students across all sections for data extrapolation, a minimum threshold of 30% was established, and data from sections whose response rate was below the threshold were not included in the study. In total, 12 sections (27%) were omitted. The sample size (outlined in Table 2) was as follows:

Fall Semester 2014
- Experimental Group (Asynchronous Online Group)
  - A&PI = 53 participants (51%) in 4 different sections taught by 2 different instructors
  - A&PII = 22 participants (51%) in 2 different sections taught by 2 different instructors
- Control Group (On-Campus Face-to-Face Instruction)
  - A&PI = 79 participants (61%) in 6 different sections taught by 6 different instructors
  - A&PII = 9 participants (64%) in 1 section

Spring Semester 2015
- Experimental Group (Asynchronous Online Group)

A&PI = 67 participants (59%) in 6 different sections taught by 5 different instructors

A&PII = 37 participants (45%) in 4 sections taught by 4 different instructors

Control Group (On-Campus Face-to-Face Instruction)

A&PI = 31 participants (54%) in 3 different sections taught by 3 different instructors

A&PII = 99 participants (59%) in 7 different sections taught by 6 different instructors

Total: 397 participants in 17 on-campus sections (N=218) and 16 online sections (N=179)

Recruitment of Participants

The primary investigator contacted all instructors assigned to teach an anatomy and physiology section(s) via email 16 days prior to the first day of the fall term, and 12 days before the spring term began. The email provided each instructor an explanation of the nature of the study, instructions for each instructor, and a script to read to his/her students. It was explained that the invitation to participate (Appendix B), research assessments (Appendices C, D, and E), and consent form (Appendix F) had been uploaded to all Blackboard sections in both modalities offered for that term. Instructors were encouraged to contact the principal investigator if they had questions or concerns. Instructors were sent the same email three days before classes began, and a follow-up email on the first day of class. On the third day of the first week of class, instructors were individually contacted and provided with the response rate in each of their sections up to that point, and encouraged to send an email or post an announcement about the study (at their discretion). The primary investigator was assigned to teach one on-campus section per semester, for a total of two sections that were involved in the study.

Enrollees in 33 sections of A&PI and A&PII offered in the fall 2014 term and spring 2015 term participated in the study. For students enrolled in the online sections, a document was posted in Blackboard inviting them to participate in the study. The posted document explained the general nature of the research, their role in the research, how the data will be used, the steps taken to maintain confidentiality, and the potential benefits of their participation to the advancement of knowledge regarding the differences and parallels of learning in various learning modalities. The contact information of the primary investigator was provided so that questions and concerns could be addressed. The primary investigator did not contact students directly via email, and it was left to the discretion of the course instructor to send an email to students or post an announcement asking students to open the Assessment Folder in Blackboard.

On-campus enrollees were invited to participate orally by their instructor during the first two class meetings. The instructor of each on-campus section read the invitation to participate document posted in the Assessment Folder in Blackboard aloud to his/her class. In addition, on-campus instructors sent emails (course messages through Blackboard) to every student in the class reminding them to review the invitation and consider participating in the study. In three on-campus sections, the primary investigator visited the class during the first week of school to read the invitation to students and address questions and concerns (this occurred in sections taught by instructors who were unfamiliar with Blackboard and/or did not feel comfortable speaking about the research with students). Students were reminded to take the post-test during the last week of class via email and orally in class by their instructor.

The demographic questionnaire, pre-test, and post-test were administered and submitted in Backboard. Students completed the assessments on their own, either at home or in a computer lab at school, without a proctor. Participants were not monetarily compensated for their role in the study. Instructors were provided the option to offer bonus points at their discretion to students who completed all three assessments, and two instructors offered bonus points for completion of all three assessments (in each case, the bonus points did not add more than 1.25 points to their overall average and therefore was inconsequential to their overall grade in the course). Participation in the study was voluntary, and it was articulated to students that both their consent and confirmation of age (18 years of age or older), would be given by clicking on a link that opened the Assessment Folder that contained the research assessments (Figure 2).

Procedure, Treatment, and Instrument

Participants in both groups (online and on-campus) were required to complete an identical series of assessments - a demographic questionnaire, pre-test, and post-test (Appendices E, F, and G). The demographic questionnaire and pre- and post-tests were completed in and submitted in Blackboard. In this study, the dependent variable, the primary outcome of interest, was student learning and was measured by improvement between baseline and post-intervention knowledge assessments. The independent variable in this study was course modality – the learning environment/teaching intervention. In addition, a standardized battery of demographic information was collected from each subject to determine their effect, if any, on learning.

Demographic data were collected using a 17-question survey instrument administered within seven days of the first class meeting. Survey questions were selected based on the assumptions that certain variables may influence and serve as predictors of student success. The learner variables assessed via the demographic survey were chosen based on previous studies' most often cited individual characteristics related to student success and persistence (Nguyen, 2015; Park & Choi, 2009; Park, 2007). The variables of interest included age, gender, GPA, prior experience with Blackboard, experience with online courses, previous science coursework (high school and/or college-level), and employment obligations. In addition to the online demographic questionnaire, a knowledge-based test was administered to permit inferences about student learning outcomes. The knowledge-based assessment consisted of a pre- and post-test design. The pre-test measurement was administered in each course section within seven days of the first class meeting (or for online courses, the first day classes began), while the post-test was administered within a seven day period immediately preceding the close of the term (Figure 1).

The main comparison of student learning between course modalities was through the pre- and post-test assessments. The demographic survey and pre- and post-test assessments were administered in each section of A&PI and A&PII over the course of two terms. The pre- and post-assessments for each course were identical, and consisted of questions designed to support the learning outcomes. The questions were derived from outcome benchmarks prescribed by *The Human Anatomy & Physiology Society* (HAPS), an international organization whose mission is to “promote excellence in the teaching of anatomy and physiology.” Each test consisted of 22 multiple choice questions covering relevant anatomy and physiology topics, including several questions to test concepts explored during the lab exercises, such as identification of anatomical structures and interpretation of graphs. Each test question was designed to measure and align with a specific course learning outcome (course learning outcomes were developed by full-time faculty members who teach the course at the study site). Prior to their implementation, the assessments were reviewed by two full-time faculty members for accuracy and adequate domain representation. The full-time faculty member assessment reviewers were tenured biology professors that had each been teaching anatomy and physiology for over six years, each with a doctorate in a field of biology. Finally, the assessments were field-tested on an independent group of anatomy and physiology students. The 19 students used for field-testing were not involved in the study, and they completed both versions of the post-test upon completion of

A&PII during the summer 2014 term (prior to the study). These students were provided the opportunity to provide specific feedback regarding the comprehensive nature of the tests, face validity, and individual question clarity. Minor grammatical revisions were made to two of the A&PI assessment questions based on the student feedback.

For A&PI, the pre- and post-assessments were the same for each course section for each term and course setting. For A&PII, the pre- and post-assessments were the same for each course section for each term and course setting. To increase the reliability of the assessment and provide more than one opportunity to demonstrate competence, two different multiple choice questions were used to assess a single learning outcome (Haladyna, Downing & Rodriguez, 2002), for a total of 22 content questions (two per learning outcome). The test was designed to be manageable for students and instructors, and not place significant time demands on the participant. According to Reynolds, Livingston, and Willson (2009), longer tests are more reliable, and having more than one test item for each outcome will result in a more accurate sample of the domain. Pre- and post-test items included for knowledge assessment (the primary dependent measure) were selected and adapted in order to achieve content validity. The questions align with HAPS's learning benchmarks, and many are used as part of a comprehensive final exam crafted by HAPS members (and at the time of the study, had been evaluated and subjected to psychometric validation) and therefore serve as a reliable indicator of internal validity. Each question utilized a multiple choice format with five answer options. A pre-determined marking scheme was used, with a maximum score of 22 (each question was worth one point). The pre- and post-tests were automatically scored by Blackboard upon submission. In addition to the knowledge-based items, the post-test included an attitude question to determine students' feelings about whether the information on the pre- and post-tests was reflective of the course content. Upon completion of the pre-test, participants were denied access to their scores and submissions in order to preserve the integrity of the questions both during and between terms. The pre-test and post-test were timed at 20 minutes, and had to be completed at one sitting (in Blackboard called “forced completion” - students cannot not save partial work to finish at a later time). Twenty minutes provided 54.5 seconds/question which, based on the field-test and instructor reviews, the primary investigator determined to be an appropriate amount of time for students to read, process, and answer all the questions (but not an excessive amount of time that allowed students to look up answers). The demographic survey did not have a time limit. Group means and range of scores are presented in Table 5.

After classes ended for each term, the scores from the pre- and post-tests were downloaded from Blackboard. The data were anonymized by removal of both participant names and school ID numbers, and each participant was assigned a numeric identifier.

Data Analyses

Data from all semesters were used to examine student learning in the control and treatment groups. Basic descriptive statistics were calculated to provide information on the background and equivalency of the groups with respect to age, ethnicity/race, gender, demands of employment obligations, science background, previous Blackboard experience, and prior online course experiences (Table 3). Group means, percentages, standard deviations, and standard error of the means were calculated where appropriate and frequency counts are provided for categorical data.

Four paired Student’s *t*-tests (one for each class/modality) were conducted to examine gains in knowledge between the administration of the pre- and post-test within each learning modality. The dependent variable for each test was the change score on the pre- and post-test knowledge-based assessment. Ninety-five percent confidence intervals were provided and Cohen's *d* was calculated as a measure of effect size.

An Analysis of Covariance (ANCOVA) was used to examine the effects of course modality on learning, as measured by the pre- and post-test - comparing scores on the knowledge-based assessment to examine changes in learning within and between the two learning modalities. The following null hypothesis was tested: *There is no statistically significant difference in pre- and post-test scores between online students and traditional on-site students completing the same anatomy and physiology courses* ($H_0 = \mu_1 = \mu_2$). An ANCOVA was used because it is an appropriately precise and sensitive test to partial out variance in the dependent variable to explicitly determine why there may be differences between effects of treatment in a before-after experimental design when there is the possibility of an interaction/correlation between a control variable and the outcome (Dugard & Todman, 1995; Knapp & Schafer, 2009; Wright, 2006).

Analyses were initially conducted to evaluate differences in the change score by modality by course to evaluate whether the course (either A&PI or A&PII) influenced gains in knowledge within each modality. Following that, data from each course in the sequence were combined and an omnibus analysis was conducted to examine differences in the change in score from pre-test (normalized by the ANCOVA) to the post-test by modality. Prior to the analysis, the data were tested for normality, equality of variance (Levene's test, pre- and post-test linear relationship), and homogeneity of regression (using the residuals from the regression analysis). For the ANCOVA, instructional modality served as the between-subjects factor, while the pre-test score served as the covariate. The post-test score served as the outcome variable. In order to estimate the difference in learning within teaching modalities, difference between least squares means and corresponding 95% confidence intervals were calculated based on the ANCOVA model.

Furthermore, partial eta squared (η^2) was calculated for all ANCOVA analyses as a measure of effect size.

A conventional stepwise entry multivariate regression model was fitted to the data to assess the influence of learner variables on the knowledge-based assessment outcome, first within each modality and then omnibus, using an exploratory model that combined the two learning modalities. Stepwise regression was used to remove researcher bias and because it was the most statistically appropriate methodology. Standardized regression coefficients (beta weights) were included to illustrate the magnitude and direction of the relationship between learning and each independent predictor variable. The self-reported learner variables of interest in the regression analysis included age, gender, race, GPA, prior experience with Blackboard, experience with online courses, previous science coursework, and employment obligations (Table 4). Predictor variables were tested for multicollinearity (none of the learner variables for either modality were found to have a collinearity tolerance less than 0.85, thus providing evidence that the variance for each learner variable was not significantly shared with one of the other learner variables). The regression models were fit using SPSS (IBM Statistical Package for the Social Sciences, Version 22.0, Armonk, NY).

A Chi-square test was used to evaluate the frequency distribution of final letter grades between the two learning modalities. The following null hypothesis was tested: *There is no statistically significant difference in grade distribution between online students and on-site students completing the same anatomy and physiology courses* ($H_0 = \mu_1 = \mu_2$).

Methodological Assumptions

Several statistical assumptions were required for the quantitative data analytic process. Statistical testing calculations rely on the assumptions that the sample sizes are reasonable and sufficiently large, the group sizes are homogenous, the observed variance is homogenous across groups, and that the dependent variable data have a normal distribution. In addition, the ANCOVA assumes a reasonable correlation between the covariate function (pre-test scores) and the dependent outcome variable, a linear relationship between the covariate and dependent variable, and homogeneity of the regression slopes.

Analogous to the assumptions made by others conducting research in this area (e.g., Jones & Long, 2013), this research rests on the assumptions that differences in scores on pre- and post-tests are accurate reflections of student achievement and conceptual learning and therefore can be used to draw conclusions from the data. In addition, it was assumed that each student completed his/her own work in the course, and that each student made an effort to succeed in the course.

CHAPTER 4: RESULTS AND DISCUSSION OF FINDINGS

Overview

This chapter presents the results of the statistical analyses used to answer the research questions addressed in the study. Results are reported for the paired samples t-tests to examine changes on the knowledge assessment for both courses and modalities, and the one-way ANCOVA used to examine the influence of course modality on the post-test knowledge assessment. Additional results are reported regarding the multiple linear regression model used to determine the effect of learner variables on the knowledge assessment for the groups combined and separate. A discussion of the findings concludes this chapter.

Results

Four paired samples t-tests were conducted to examine changes in the knowledge assessment from pre- to post-test in each class, A&PI or A&PII, and by modality, on-campus or online. Paired samples t-tests conducted in A&PI on-campus sections indicated there was a significant improvement in scores from pre-test to post-test, $p < 0.001$. Paired samples t-tests conducted in A&PI online sections indicated there was a significant improvement in scores from pre-test to post-test, $p < 0.001$. Paired samples t-tests conducted in A&PII on-campus sections indicated there was a significant improvement in scores from pre-test to post-test, $p < 0.001$. Paired samples t-tests conducted to examine changes in A&PII online sections indicated there was a significant improvement in scores from pre-test to post-test, $p < 0.001$. The results of the paired samples t-tests are presented in Table 5 and pre-/post-test means are presented in Figure 3.

Two one-way ANCOVAs were conducted to examine the influence of course modality on performance on the post-test knowledge assessment, controlling for the influence of pre-test scores in A&PI and A&PII sections. The analysis of A&PI section data revealed that course modality did not have a significant effect on post-test knowledge assessment after controlling for pre-test performance, F(1,227) = 2.58, $p > 0.05$. Likewise, the analysis of A&PII section data indicated that course modality did not have a significant effect on post-test knowledge assessment after controlling for pre-test performance, F(1,164) = 0.79, $p > 0.05$.

Following the perfunctory analysis of the influence of course modality on knowledge assessment performance, the data for A&PI and A&PII were combined and a one-way ANCOVA was conducted to examine the broader influence of modality on performance gains. This analysis indicated that course modality did not have a significant effect on post-test knowledge assessment after controlling for pre-test performance, F(1l,394) = 0.16, $p > 0.05$. Thus, one can conclude that, irrespective of the type of course delivery, learning gains were not affected by modality.

Initially, an omnibus multiple linear regression model was used to test if the learner variables (independent variables) significantly predicted subjects' performance on the knowledge assessment (dependent variable), as measured by the change score that was calculated from pre- and post-test performance. The null hypotheses tested were that the multiple R^2 was equal to 0 and that the regression coefficients were equal to 0. The assumption of linearity in the model fit was met, $p < 0.001$. A scatterplot of unstandardized residuals to predicted values provided further evidence of linearity. The assumption of normality was tested via examination of the unstandardized residuals. Skewness (0.21) and kurtosis (0.14) statistics suggested that normality was a reasonable assumption as the acceptable range is between -2 and 2 (George and Mallery, 2010). Additionally, the Q-Q plot of standardized residuals by predicted values and histogram of standardized residuals were demonstrative of normality and provide evidence that homoscedasticity was reasonable and box plots suggested a relatively normal distributional shape (with no outliers) of the residuals. A frequency distribution of change score of combined groups is presented in Figure 4. Scatterplots of standardized residuals against predicted values and against values of the independent variables displayed a relatively random display of data points, thus providing evidence of independence. Additionally, the reported Durbin-Watson statistic was $d = 1.71$, therefore it can be assumed that there is no first-order auto-correlation in the multiple regression model. Multicollinearity was examined and tolerance was demonstrated to be > 0.20 (lowest independent variable tested at 0.83) and the variance inflation factor was < 10 (greatest value was 1.20), suggesting that multicollinearity is not an issue/concern.

Using the stepwise entry method, it was found that the learner variables (independent variables) explain a significant amount of the variance in the subjects' performance on the knowledge assessment (dependent variable), $p < 0.001$. The analysis shows that GPA, $p < 0.001$, and the number of online courses previously taken, $p < 0.01$, significantly predicted performance on the learning assessment (Figures 5 and 6). However, age, gender, race, previous number of biology courses, work hours, and prior Blackboard experience did not predict performance on the knowledge assessment and thus they were excluded from the final model ($p > 0.05$). A summary of the stepwise regression analysis can be found in Table 6 and the regression model is depicted in Figure 7. Reported GPAs were compared to institutional GPAs from the subsequent academic term using a post-hoc two sample t-test, and GPA was found to be reliably reported, as there was no statistical difference between the reported mean GPA (3.29) and actual mean GPA (3.27), $t(462) = 0.32$, $p > 0.05$.

Finally, two multiple linear regression models, one for each learning modality, were used to test if the learner variables (independent variables) significantly predicted subjects' performance on the knowledge assessment (dependent variable), as measured by the change score that was calculated from pre- and post-test performance. The null hypotheses tested were that the multiple R^2 was equal to 0 and that the regression coefficients were equal to 0. The assumption of linearity in the model fit was met for both models, $p < 0.01$. A scatterplot of unstandardized residuals to predicted values provided further evidence of linearity for each learning modality. The assumption of normality was tested via examination of the unstandardized residuals. The analysis revealed no skewness (online = 0.35, on-campus = 0.10) or kurtosis (online = 0.44, on-campus = 0.01). Additionally, the Q-Q plot of standardized residuals by predicted values and histogram of standardized residuals were demonstrative of normality and provide evidence that homoscedasticity was reasonable and box plots suggested a relatively normal distributional shape (with no outliers) of the residuals. A frequency distribution of the change scores for the on-campus and online groups are presented in Figures 8 and 9. Scatterplots of standardized residuals against predicted values and against values of the independent variables displayed a relatively random display of data points, thus providing evidence of independence. Additionally, the reported Durbin-Watson statistic for online was d = 2.01, and for on-campus was d = 1.40; therefore it can be assumed that there is no first-order auto-correlation in the multiple regression model. Multicollinearity was examined and tolerance was demonstrated to be > 0.93 for online and > 0.92 for on-campus, and the variance inflation factor was < 10 (greatest value was 1.08), suggesting that multicollinearity was not an issue for either modality.

Using the stepwise entry method for the online group, the learner variables explain a significant amount of the variance in the subjects' performance on the knowledge assessment, $p < 0.001$. The analysis showed that GPA significantly predicted performance on the learning assessment, $p < 0.001$ (Figure 10). The number of online courses previously taken, age, gender, race, previous number of biology courses, work hours, and prior Blackboard experience did not predict performance on the knowledge assessment and thus they were excluded from the final model ($p > 0.05$) (Table 7).

Using the stepwise entry method for the on-campus control group, the learner variables explain a significant amount of the variance in the subjects' performance on the knowledge assessment, $p < 0.01$. The analysis shows that GPA, $p < 0.01$, (Figure 11) and employment hours, $p < 0.05$ (Figure 12) significantly predicted performance on the learning assessment. The number of online courses previously taken, age, gender, race, previous number of biology courses, and prior Blackboard experience did not predict performance on the knowledge assessment, and thus they were excluded from the final model ($p > 0.05$) (Table 8).

A Chi-square test evaluated the final grade distribution across learning modality and indicated that there was a difference in the grade distribution between the two instructional methods, X^2 $(12, N=397) = 26.15$, $p = 0.01$. A breakdown of the final grade distribution within each course modality can be found in Table 9.

Discussion

The main focus of this study was to determine if an online anatomy and physiology learning environment could promote conceptual learning gains on par with those in a traditional face-to-face learning environment. The following null hypothesis was tested: *There is no statistically significant difference in pre- and post-test scores between online students and traditional on-site students completing the same anatomy and physiology courses*. To address how the effectiveness of fully-online instruction compares with that of traditional face-to-face classroom/lab instruction in terms of conceptual learning, the current study evaluated performance using pre- and post-test assessments.

The results of this study indicate that all courses, regardless of modality or section, experienced statistically significant improvement in scores from pre- to post-test (Table 5). Despite higher pre-test scores in A&P I and II online groups, and a greater increase in pre-test to post-test scores in A&P I and II on-campus group, the difference in learning between modalities was not statistically significant based on the ANCOVA. The pre-test and post-test ranges for both modalities were similar, with 21/22 being the highest post-test score in the on-campus groups, and 22/22 in the online groups. There were fewer negative change scores observed in the online groups compared to the on-campus groups, however, there was a greater number of zero change scores in the online groups. For online groups, the greatest number of change scores was clustered between 0-6, and in on-campus groups, clustered between 1-7; however both groups experienced a change score mode of three, and both groups had similar frequencies of participants with change scores of 10 or greater. Learning gains, measured by the difference in scores on pre- and post-treatment measurements, occurred in all groups, and indicated no statistically significant differences in learning by modality after controlling for pre-test performance. These data suggest that content and conceptual competency was similarly achieved for all courses and both modalities, and the present findings are consonant with the findings of similar research exploring learning in an online medium or incorporation of an online/virtual component in other subject areas (e.g., Dobson, 2009; Finkelstein et al., 2005; Gilman, 2006; Gonzalez, 2014; Hallgren et al., 2002; Johnson, 2002; Reuter, 2009; Rifell & Sibley, 2005; Zacharia & Olympiou, 2011).

Since the prerequisites for each course are the same regardless of modality (high school biology is the minimum institutional prerequisite for A&P I), it was expected that the pre-test mean scores would be similar in both groups. However, the online groups had slightly higher mean scores on the pre-tests in A&P I and II. Pre-test means for on-campus groups were lower than those in the online groups by at least 1.4 points (out of a possible 22 points) (Table 5). The score variation diminished on the post-test means among the groups (although online post-test means were still slightly higher). Although this difference was controlled for in the ANCOVA, the pre- and post-test mean differences between the groups may be cursorily explained by a number of factors. The online group had a higher mean age compared the on-campus group (29 years versus 24 years) (Table 3). Studies indicate that non-traditionally-aged students tend to be more focused on seeking knowledge and have higher levels of persistence, motivation, and emotional intelligence (Berenson, Boyles & Weaver, 2008; Bye, Pushkar & Conway, 2007). As students self-selected their learning modality, it is possible that students with higher levels of maturity and motivation enrolled in the online course sections, as student motivation was not explored in this study. Since a larger percentage of online students reported previous completion of online coursework, they may exhibit higher levels of self-regulation and time-management - and therefore may be more likely to thrive in an online environment. Greater time-management skills are further supported by comparing work obligations, as 60% of the online students reported working 31 or more hours per week, versus only 22% of on-campus students (Table 3). Lastly, an additional factor that may explain the slightly higher pre-test scores among the online group is the level science background, measured by the number of college-level science courses completed prior to taking anatomy and physiology. Online students reported a stronger science background, completing an average of at least one additional science course prior to anatomy and physiology enrollment – thus, they may have had more exposure to science content at the onset of the course when the pre-tests were administered. It is important to note that the statistical approach used in this study, an ANCOVA, was selected specifically to address any pre-test differences among groups, allowing a more precise detection of the effect of the teaching intervention. In addition, the regression analysis provided a more accurate assessment of predictor variables on performance. The fact that the results of this study demonstrate that learning is equivalent across modalities, should not be particularly surprising in light of the fact that the content covered in each course is the same, and while the delivery medium is different, what students are required to learn and the adopted textbook are the same across modalities.

To answer the second research question, which addresses the influence of learner characteristics on outcomes, multiple regression analysis revealed that few learner variables were found to predict performance in both the online and on-campus groups. As multicollinearity was not found to be an issue in the explanatory regression model, the beta weights provide an accurate measure of the total contribution of GPA and previous online course experience to the dependent variable in this study, and those variables account for approximately 8% of the variance in learning, and should be considered relevant in terms of predictive modeling (Table 6 and Figure 7). It is not remarkable that GPA was found to be a predictor of success and an influential variable that explains meaningful differences in learning, as previous studies regarding predictors of online success had similar findings (e.g., Diaz, 2000; Gerlich, Mills & Sollosy, 2009; Harrell & Bower, 2011; Roblyer & Davis, 2008; Wilson & Allen, 2011; Wojciechowski & Palmer, 2005). It is logical to hypothesize that an achievement-oriented student with a strong academic background will do well in other classes, including online classes

(Berenson et al., 2008); hence, students who had been previously successful were more likely to continue to be successful.

This study used familiarity with Blackboard and the number of previous online courses to serve as a measure of computer literacy, assuming the more experience a student had taking online classes, the greater the level of comfort and expertise he/she would have navigating an online learning platform. Interestingly, student learning in the omnibus analysis was found to be negatively correlated with the number of online courses previously completed (Table 6). This inverse relationship contradicts expectations and previous studies that found a positive and statistically significant relationship between previous online coursework and grade in the course (e.g., Lim, Morris & Yoon, 2006; Wojciechowski & Palmer, 2005). The performance decrement indicated by the data may be explained not by lack of computer literacy, but may be due in part to lack of experience with online science courses as opposed to online experiences in other disciplines, as there appear to be no studies that specifically explore such variables in online anatomy and physiology courses. Due to the paucity in the research on this topic, there are no studies with which to compare these results.

As expected, the number of employment hours was a significant predictor of learning in the on-campus group. Regression analysis of the on-campus group showed that fewer hours of employment per week was correlated with greater learning gains (Table 7). A previous study on predictive modeling indicated that online students who worked between 1-10 hours per week had higher chances of success and completion, even when compared to students who did not work (Simpson, 2006), however this study found no such inverse relationship. Therefore, the present findings suggest that although the courses cover the same content and are similarly rigorous, the inherently asynchronous flexible nature of the online courses in this study may have accommodated students with greater employment demands to complete the assignments around their schedules, while the on-campus students were not afforded the same flexibility.

Gender was not a predictor of learning, which coincides with more recent findings regarding gender differences in performance and completion in online and other technology-driven courses (e.g., Daymont & Blau, 2008; Lim, Morris & Yoon, 2006; Park & Choi, 2009; Price, 2006; Yukselturk & Bulut, 2009). Similarly, there was no effect of age as a predictor of success, a finding that is consonant with previous findings (e.g., Gerlich, Mills & Sollosy, 2009; Yukselturk & Bulut, 2007). Gerlich et al. (2009) assert that any differences found related to age, even if non-significant, are "likely to be minimized over time" as more and more students enter college with a greater level of computer and technology acumen (p. 8). Thus, given the findings of prior research, it is not particularly surprising that age and gender were not predictors of online success.

Few studies explore the relationship between race/ethnicity and differential learning in online and on-campus science courses. However, a recent large-scale study exploring the impact of ethnicity and other characteristics of community college STEM students found no interaction between course modality and ethnicity (Wladis, Conway & Hachey, 2015). The results of this study echo that finding and therefore are not remarkable.

Chi-square results show a significant difference in final letter grades between the two modalities. The data show that 93% of students in the online group successfully completed the class (with a grade of "C" or better), while only 82% of students in the on-campus group successfully completed the class (with a grade of "C" or better) (Table 9). That the online success rate exceeded the on-campus success rate (measured by assigned letter grade) may be partially explained by the greater flexibility and dynamic nature of the online environment, which allows students to complete the assessments within a time-frame, but not at a specific and designated time. In addition, the assessment structure may have influenced the success rate in the course. The online course format incudes a greater number of assessments, each of which covers less breadth than the assessments in the on-campus groups – the online courses have 9 shorter weekly exams, each covering an average of 1-2 chapters, whereby the on-campus sections utilize a fewer number of assessments, typically 3-4 exams that each cover 3-4 chapters on average. Recent studies in anatomy and other health-related physiology courses have revealed that repeated testing and more frequent participation in formative exams/quizzes were positively correlated to higher summative exam scores and overall averages, presumably because of increased retrieval practice, increased efficacy of study time, and enhanced learning (Palmen, Vorstenbosch, Tanck & Kooloos, 2015; Panus, Stewart, Hagemeier, Thigpen & Brooks, 2014; Poljicanin, Caric, Vilovic, Kosta, Guic, Aljinovic & Grkovic, 2009). Karpicke and Blunt (2011) address the benefits of active retrieval practice to promote conceptual learning in science. They assert that frequent retrieval activities enhance meaningful learning more than other study processes. To this end, the structure and schedule of the online course assessments may provide greater opportunities for retrieval, by way of frequency, and therefore serve as mechanisms of enhanced long-term memory retrieval-practice. In this way, learning is augmented, regardless of other elaborative study techniques. Although their study has been criticized for endorsing frequent testing (Mintzes et al., 2011), methods that encourage retrieval from long-term memory are likely to provide a benefit, especially in an online environment. Such assessment strategies have been shown to be effective in on-campus anatomy and physiology courses, and promote greater learning in such environments – due to increased opportunities for recall and recognition by way of more frequent assessments. In this way, learning may be enhanced, regardless of other elaborative study techniques. An additional factor that may have impacted final grades in the course is the weighted value of various assessments in the courses. In the online course sections, there is rigid standardization of each assessment's contribution to the student's final overall average. The percentage of how much homework, exams, and lab assignments contribute to the final overall average was the same for each online section, with lab practicals and exams constituting 70% of a student's overall grade. In the on-campus sections, institutional constraints and academic freedom prohibit such rigid standardization and therefore each individual instructor determined the weight of each assessment's raw score when calculating the final overall average. Thus, some instructors may have put more emphasis on exams, while others may have put more emphasis on lab work, or vice versa – which may have influenced the overall grade distribution. Other factors that are not immediately evident in the findings may have also influenced the disparity in grade distribution between the groups, such as the degree of motivation of self-selected online students. Similar to other research (e.g., Wilson & Allen, 2011), both class modalities exhibited similarly low withdrawal/drop rates (<1%), which may be related to learner characteristics not explored in this study (such as maturity, motivation, emotional intelligence, self-regulation, independent learning skills, and time management skills).

CHAPTER 5: CONCLUSIONS

Overview

This section includes a synthesis of the major conclusions drawn from this research. It concludes with a description of the implications and significance of this research for higher education and practitioners, the limitations of the research, and recommendations for future research.

Summary and Conclusions

This research provides an empirical basis for linking the current, although fragmented, theories regarding adult online learning to natural science courses. This research affirms that those components integral to fostering an engaging learning context for conceptual knowledge attainment with regards to comprehension and application can be achieved in an online anatomy and physiology course, and challenges the established pedagogic norms concerning anatomy and physiology. The data from this study support the hypothesis that there is no statistically significant difference in pre- and post-test scores between online students and traditional on-site students completing the same anatomy and physiology courses. Despite concerns voiced by some SUNY faculty and administrators regarding the equivalency of learning critical content in online classes, resulting in questionable transferability, the findings of this study, as well as a majority of studies in other disciplines (including business, computer science, humanities and social science) indicate that conceptual learning is equivalent. This study, one of the first to be conducted in anatomy and physiology courses, confirms previous studies that have found no significant difference in learning between online and on-campus students. However, it must be emphasized that no conclusions can be drawn regarding higher-order critical thinking gains or laboratory skills as they relate to clinical practice and patient assessment, as these components were not integrated into the online experience in the online courses included in the study.

Science courses have traditionally been taught with their own distinctive theory-development approaches (Kennepohl, 2009). Such courses have a legacy of experimental methodologies to promote learning that some believe cannot be replicated in a virtual environment; however the results of this study indicate that an online environment can provide an effective medium to support conceptual understanding among anatomy and physiology students. Based on these and similar findings (addressed in Chapter 2), and the popularity of online courses, it can be anticipated that online biology courses will play an even greater role in, and make significant contributions to, science education, as these courses can provide a viable alternative to traditional classroom-instructed science courses. One of the most salient consequences of the present findings is the potential implication for colleges and universities that want to implement technology-based online learning into biology courses and health-related degree programs.

There is a momentum of change occurring in education – a transformative paradigmatic shift towards technology-based education environments. As such, it is quite possible that virtual technologies may emerge as the dominant content-delivery medium in higher education. The last decade has witnessed an exponential expansion of software technologies in the education sector, and as such, the ability of these technologies to enhance and foster learning experiences has also increased. Technological advances have provided the foundation for online learning platforms that allow students to access to quality learning opportunities around the world. However, it must be emphasized that conclusions based on research that was conducted a decade or more ago are constrained by the quality and utility of the technology and software available at that time, and therefore should be less seriously considered when determining the effectiveness of virtual class/lab experiences. More recent research is likely to be based on the most current, up-to-date, and contemporary instructional software, and therefore courses utilizing more evolved and sophisticated technologies are likely to enhance and advance learning (perhaps even individualized learning) even more. As the instructional value of simulation software improves over time, its effect on learning is likely to improve as well, and therefore may be expected to outperform earlier forms of distance education (Zhao, Lei, Yan, Lai & Tan, 2005). This may (at least in part) explain why studies published before the turn of the millennium generally did not find significant differences between distance education and traditional education, but studies published afterwards generally find significant differences in favor of online education (Nguyen, 2015).

Recommendations and Future Research

The results of this study are not definitive or exhaustive, as this study was executed using a quasi-experimental design that relied on voluntary participation. The study was conducted at one school over a short period of time (two semesters) and therefore the results may not be generalizable to other settings or populations of adult learners. Expanding this study to include a greater number of students and academic terms would help strengthen the conclusions made regarding learning anatomy and physiology in an online environment. As there are few analogous research studies that analyze conceptual learning in completely online asynchronous anatomy and physiology courses, the results of this study cannot be compared with previous studies. It is customary and foreseeable in such studies to conclude that more research is necessary, and in this specific case… it is a valid conclusion. Though the results are compelling, this was the first exploration in this arena. Additional research on asynchronous online anatomy and physiology courses is needed to provide more nuanced conclusions, especially studies that assess higher-order critical thinking skills as well as acquirement of procedural laboratory skills. In addition, research that also includes a qualitative component to addresses perceptions, levels of interaction, and social presence would provide valuable information. Furthermore, research that involves a systematic approach to learning theories and online course design will no doubt have the largest impact on what can be gleaned regarding learning science in an online environment. Lastly, research that further explores the relationship between online biology course success and the type(s) of online courses previously completed (by department code) would be enlightening.

Despite the limitations, this study provides valuable contributions to education research. The strengths of this study are grounded in a rigorous data collection process, validated instruments, a large sample, and powerful and robust data analytic procedures. Consequently, this research provides unambiguous results regarding student conceptual learning in on-campus and online modalities, providing evidence that that course quality and rigor can be similarly achieved for on-campus and online anatomy and physiology courses. The results of this study support the hypothesis that there is no significant difference in conceptual learning between online and on-campus modalities in anatomy and physiology courses. Consequently, these data can be used to make institutional decisions that will impact students, pedagogues, course structure, and curricular offerings.

The contribution of this research to science education is multidimensional. First, researchers and practitioners can apply the results of this study to help identify/predict learner variables as influencing mechanisms of success in both online and on-campus anatomy and physiology courses. Such information can be used by institutions to determine student characteristics that are congruent with empirically-identified factors associated with successful outcome attainment in natural science courses. Perhaps more importantly, as online enrollment is expected to continue and expand, institutions can develop profiles of students expected to succeed in anatomy and physiology and other online biology courses. This information can help such institutions maintain heightened awareness in regards to provision of support services and resources for course sections with a large number of students deemed at-risk, as well as determine circumstances in which online anatomy and physiology course advisement be contraindicated. Second, it is possible to make inferences about the factors that contribute to meaningful learning based on the grade distribution between the modalities. Online students performed better on formative assessments, resulting in higher grade assignment, which may be partially explained by the course and assessment structure. Therefore, pedagogical methods deemed successful in online courses may have equal success when integrated into on-campus course models. Third, the results of this study can be used to inform the ways in which learning in online anatomy and physiology courses parallels that of its physical on-campus counterpart, and prompt further research in this area. This study is the first to provide empirical evidence that conceptual learning (knowledge comprehension, and application of content) in anatomy and physiology can be achieved in a fully online asynchronous format. This information can be applied to assist institutions when making strategic considerations regarding how these courses are implemented, when they are offered, if they are acceptable for transfer, and how their benefits can be utilized in higher education to reach and attract STEM students.

Based on the findings of this research, it is recommended that NYS higher education institutions and SUNY continue to support research in, implementation of, and transfer/acceptance of online science courses. Online learning will no doubt continue to change the tapestry of academic offerings and widen opportunities for students who, due to geographic, financial, temporal, or other limitations, were previously unable to attend traditional on-campus lab science classes. Distance education via an online medium can be a powerful method to combat historical barriers that have prevented equal access to education. As such, the education monopoly that has been historically held by physical classroom environments may diminish over time. As online course platform technologies advance, and more institutions, pedagogues, and students embrace and utilize the potentials of online learning environments, their growth is expected to continue to accelerate across all disciplines and programs – including the natural sciences.

APPENDIX A

Syracuse University IRB Exempt Status Approval Memorandum

SYRACUSE UNIVERSITY
Institutional Review Board
MEMORANDUM

TO:	John Tillotson
DATE:	March 20, 2015
SUBJECT:	**Determination of Exemption from Regulations**
IRB #:	15-102
TITLE:	*A Quantitative Assessment and Comparison of Conceptual Learning in Online and Classroom-Instructed Anatomy and Physiology*

The above referenced application, submitted for consideration as exempt from federal regulations as defined in 45 C.F.R. 46, has been evaluated by the Institutional Review Board (IRB) for the following:

1. determination that it falls within the one or more of the five exempt categories allowed by the organization;
2. determination that the research meets the organization's ethical standards.

It has been determined by the IRB this protocol qualifies for exemption and has been assigned to categories **1** and **2**. This authorization will remain active for a period of five years from **March 20, 2015** until **March 19, 2020**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://orip.syr.edu/human-research/human-research-irb.html Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: Study completion is when all research activities are complete or when a study is closed to enrollment and only data analysis remains on data that have been de-identified. A Study Closure Form should be completed and submitted to the IRB for review (Study Closure Form).

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy Cromp, M.S.W.
Director

DEPT: Science Teaching, 112 Heroy **STUDENT:** Joel Humphrey

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121 Bowne Hall Syracuse, New York 13244-1200
(Phone) 315.443.3013 ♦ (Fax) 315.443.9889
orip@syr.edu ♦ www.orip.syr.edu

APPENDIX B

Recruitment Form

Recruitment Form Posted in Blackboard

My name is Joel Humphrey and I am a Professor at (College), a State University of New York (SUNY) Institution, and also a Ph.D. student in the Department of College Science Teaching at Syracuse University. (College) is conducting research for the State University of New York comparing student performance in our online and on-campus Anatomy and Physiology classes. I am also using the data collected as part of a dissertation project at Syracuse University.

If you are taking Anatomy and Physiology I and/or Anatomy and Physiology II at (College), you are eligible to participate.

This research project will be performed by comparing performance on pre- and post-tests by online students with the performance on the same exams of on-campus students. The pre- and post-tests will each take approximately 20 minutes to complete. In addition to the pre- and post-tests, in order to learn more about the students who take Anatomy and Physiology at (College), there is a survey that contains standard demographic questions. The survey will take approximately 5 minutes of your time to complete.

If you have any further questions contact me via email at Humphrey@(college)-cc.edu, or via phone at 315.294.9039.

APPENDIX C

Demographic Survey

1. Have you taken this course demographic survey previously in A&PI or A&PII?
    - Yes
    - No

2. Age
   (respondents self report)

3. Gender
    - Male
    - Female
    - Transgender

4. Are you Hispanic or Latino?
    - Yes
    - No

5. Which race do you identify yourself as?
    - American Indian or Alaska Native
    - Asian
    - Black or African American
    - Native Hawaiian or Other Pacific Islander
    - White
    - Other/Unknown

6. Are you using this course as a pre-requisite for a program?
    - Yes
    - No

7. If you answered "Yes" to the question above, what type of program is this course a pre-requisite for?
    - Nursing
    - Health Sciences Profession (such as Radiation Therapy, Radiology, Physical Therapy, Medical Technology, Pharmacy, Respiratory Therapy, or related Health profession)
    - Science (such as Biology, Chemistry, Physics, Geology, Engineering, or a related Science degree)
    - Physical Education
    - Other
    - Not Applicable

8. If you are currently enrolled in a program, what type is it?
    - Nursing
    - Health Sciences Profession (such as Radiation Therapy, Radiology, Physical Therapy, Medical Technology, Pharmacy, Respiratory Therapy, or related Health profession)
    - Science (such as Biology, Chemistry, Physics, Geology, Engineering, or a related Science degree)
    - Physical Education
    - Other
    - Not Applicable

9. What type of institution are you currently enrolled in or hope to enroll in upon completion of your pre-requisite courses?
    - SUNY community college

- SUNY 4-year and/or graduate degree institution
- 4-year public college or university other than SUNY
- 2-year public college or university other than SUNY
- Private New York state institution
- Private out of state institution
- Other

10. How many biology courses have you taken prior to taking this course? (Please indicate with a number value, for example, 0, 1, 2, 3…)
    (respondents self report)

11. How did you find out about this course?
    - From faculty/staff at the college I currently attend
    - From faculty/staff at the college I plan to attend
    - From the SLN (SUNY Learning Network) Website
    - Word of mouth - from someone who took the course or knew about it
    - Web search
    - Other

12. What is your GPA? (Please indicate with a number value)
    (respondents self report)

13. How many credits are you currently taking (including this course)?
    (respondents self report)

14. How many hours do you work at a paying job?
    - 0
    - 1-10
    - 11-20
    - 21-30
    - 31-40
    - 41 or more

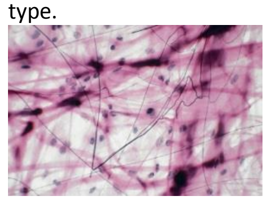
15. How many online classes have you taken prior to this semester?
    - 0
    - 1
    - 2
    - 3
    - 4
    - 5 or more

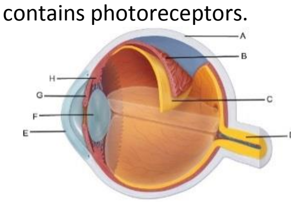
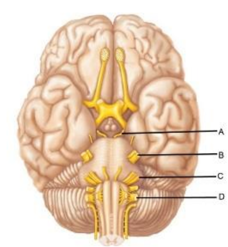
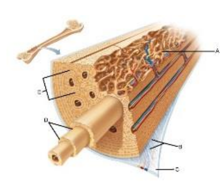
16. Have you ever used Blackboard before?
    - Yes
    - No

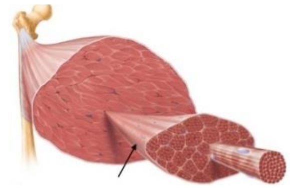
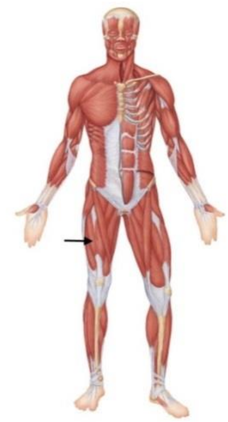
17. In what modality are you taking this course?
    - On-campus
    - Online

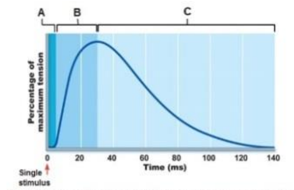
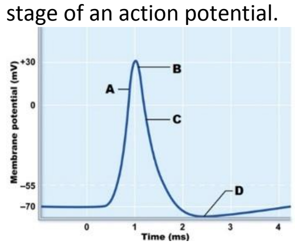
Appendix D

A&P I Assessment Instrument: Pre-/Post-Test and Linked Learning Outcomes

A&P I Pre/Post Test						
Test Question Numbers	Topic(s)	Learning Outcome (Adapted from HAPS)	Cognitive Level(s) of Outcome	Fundamental Content Goal(s) Targeted	Question 1	Question 2
1,2	Directional terms/Basic terminology	Describe the location of body organs, structures, cavities, regions, and planes using appropriate anatomical terminology.	Knowledge, Comprehension	1,2,5	The fingers are ______ to the elbow. proximal distal inferior superior superficial	The ___ plane runs longitudinally and divides the body into right and left sides. frontal transverse sagittal coronal proximal
3,4	Intracellular organization of nucleus and cytoplasm/Organelles/Membrane structure and function	Describe the basic structure of a cell and cell membrane and the functions of its components.	Knowledge, Comprehension	1,2	The plasma membrane not only provides a protective boundary for the cell but also determines which substances enter or exit the cell. This characteristic is called simple diffusion membrane potential osmosis facilitated reabsorption selective permeability	This organelle is responsible for providing most of the ATP needed by the cell. lysosome smooth endoplasmic reticulum mitochondria ribosome Golgi apparatus
5,6	Microscopic anatomy/Overview of histology and tissue types	Identify and contrast the general features of the four major tissue types.	Knowledge, Analysis	1,2	Identify the following tissue type.  Smooth muscle Connective Epithelial Nervous Skeletal muscle	Which type of epithelium covers the body and serves as protection for the body surface? simple squamous stratified squamous transitional pseudostratified columnar cuboidal
7,8	Application of homeostatic mechanisms/ Predictions related to homeostatic imbalance, including disease states and disorders	Explain the types of integrated regulatory responses of different organ systems and how they relate to one another to maintain homeostasis.	Analysis, Application	1,2,3,4,5,6,8	If a person is injected with a toxin that blocks acetylcholine receptors, what symptom would you expect to observe in the patient? loss of bone density muscle paralysis loss of vision elevated blood glucose levels muscle spasticity and tetanus	When you eat a candy bar, the sugar is absorbed into your blood, and as a result, insulin is released to lower your blood sugar. This is an example of negative feedback because the response amplifies the change. positive feedback because the response amplifies

						the change. negative feedback because the response opposes the change. positive feedback because the response opposes the change. positive feedback because it has a positive outcome and is beneficial to body homeostasis.
9,10	Gross and microscopic anatomy - nervous system and special senses	Identify the location and describe the structure and function of the major anatomical structures of the eye, ear, brain, and spinal cord.	Knowledge, Comprehen sion	1,2,7	Identify the structure that contains photoreceptors.  A B C D	Identify the nerve that contains mixed fibers – carrying somatic motor impulses to, and sensory fibers from, the pharynx, and larynx and also contains a large amount of parasympathetic motor fibers that supply the heart and smooth muscle of the abdominal organs.  A B C D
11,12	Gross and microscopic anatomy – location and function of bones and bone markings	Identify individual bones and bone markings and describe their function.	Knowledge, Comprehen sion	1,2,7	Identify the following bone structure.  Medial condyle Lateral epicondyle Head Greater trochanter	Identify “D” in the following image.  Lacuna Perforating canal Periosteum Lamella

13,14	Gross and microscopic anatomy - location and function of the major skeletal muscles	Identify the location and function of the major skeletal muscles.	Knowledge, Comprehen sion	1,2,7	Identify the following structure.  Muscle fiber Fascicle Perimysium Myofibril	Identify the following muscle.  Sartorius Gastrocnemius Brachioradialis Rectus femoris
15,16	Survey of body systems	Describe the function of the organs and accessory structures of the integumentar y system.	Knowledge, Comprehen sion	1,2	In the integument, which of the following is a protective response against the damaging effects of ultraviolet radiation? decreasing elastic fibers increasing melanin production increasing the thickness of the dermis increasing collagenous fibers increasing the blood circulation to the skin	The epidermis consists of multiple layers of cells, each layer with a distinct role to play in the health, well-being, and functioning of the skin. Which of the following layers is responsible for mitosis and replacement? corneum granulosum basal lucidum papillary
17,18	Survey of body systems//Classif ication, structure, and function of joints	Describe the function of the organs, structures, and articulations of the skeletal system.	Knowledge, Comprehen sion	1,2	Which of the following is associated with intramembranous ossification? a bone collar forms around a cartilage model an ossification center forms in fibrous connective tissue the epiphyseal plate fuses osteoclasts form a medullary cavity in long bones sarcomeres form in a central canal	Which of the following is a type of diarthrotic joint? synovial fibrous cartilaginous suture myogenic
19,20	Survey of body systems	Describe the function of the organs and structures of the muscular system.	Knowledge, Comprehen sion	1,2	This myogram shows the three phases of an isometric muscle twitch. Identify the phase labeled “A”.	Calcium is important in skeletal muscle contraction because it causes the troponin and tropomyosin molecules to expose active sites on actin

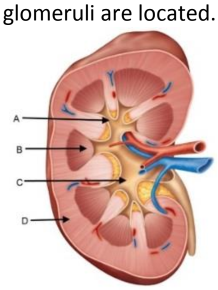
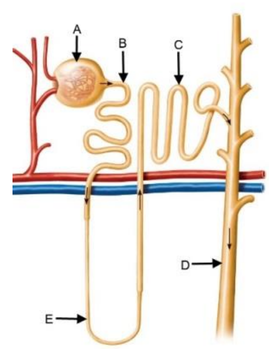
					Myogram showing the three phases of an isometric twitch Contraction Latent Refractory Relaxation Tetany	directly provides the energy needed to put the myosin head in its high-energy or cocked position leaves the muscle fiber and moves into the extracellular compartment during contraction provides the intercellular matrix support for myoblast cells is stored in the sarcoplasmic reticulum during contraction
21,22	Survey of body systems	Describe the function of the organs and structures of the nervous system.	Knowledge, Comprehen sion	1,2	The following graph shows the voltage changes that occur over time during the course of an action potential. Identify the depolarization stage of an action potential.A B C D	To digest a large meal, an individual at rest would be primarily under the influence of the sympathetic division of the autonomic nervous system aldosterone released by the endocrine system motor activity of the somatic nervous system sensory activity of the somatic nervous system the parasympathetic division of the autonomic nervous system
23		Attitude Question			Do you feel as though the information covered on this test was addressed in class/lab? Yes No	

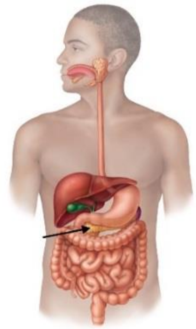
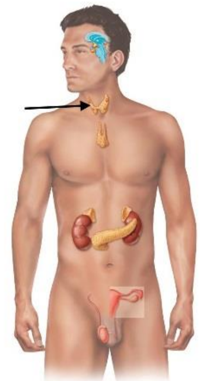
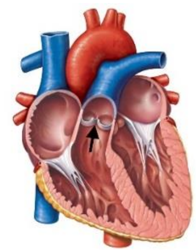
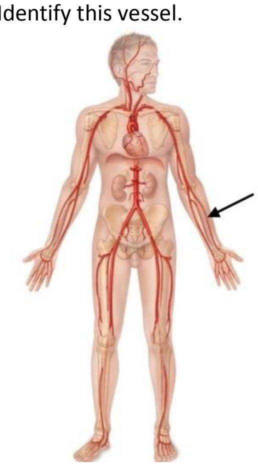
These goals form the unifying foundation for all topics in anatomy and physiology and are to be emphasized throughout Anatomy and Physiology I and II. They are directly linked to the learning outcomes written by the HAPS Curriculum & Instruction Committee:

1. Develop a vocabulary of appropriate terminology to effectively communicate information related to anatomy and physiology.
2. Recognize the anatomical structures and explain the physiological functions of body systems.
3. Recognize and explain the principle of homeostasis and the use of feedback loops to control physiological systems in the human body.
4. Use anatomical knowledge to predict physiological consequences, and use knowledge of function to predict the features of anatomical structures.
5. Recognize and explain the interrelationships within and between anatomical and physiological systems of the human body.
6. Synthesize ideas to make a connection between knowledge of anatomy and physiology and real-world situations, including healthy lifestyle decisions and homeostatic imbalances.
7. Demonstrate laboratory procedures used to examine anatomical structures and evaluate physiological functions of each organ system.
8. Interpret graphs of anatomical and physiological data.

Appendix E

A&P II Assessment Instrument: Pre-/Post-Test and Linked Learning Outcomes

A&P II Pre/Post Test						
Test Question Numbers	Topic(s)	Learning Outcome (Adapted from HAPS)	Cognitive Level(s) of Outcome	Fundamental Content Goal(s) Targeted	Question 1	Question 2
1,2	Application of homeostatic mechanisms/ Predictions related to homeostatic imbalance, including disease states and disorders	Explain the types of integrated regulatory responses of different organ systems and how they relate to one another to maintain homeostasis.	Analysis, Application	1,2,3,4,5,6,8	A patient was in a car accident and has suffered form an episode of severe hemorrhage. In order to restore homeostasis of her blood pressure, her compensatory response would include decreased reabsorption of water by her kidney tubules vagus nerve stimulation of her cardiac muscle decreased secretion of antidiuretic hormone inhibition of the renin-angiotensin mechanism stimulation of venules by the parasympathetic nervous system	A patient is losing bone density and is found to have hypercalacemia. Based on this data, which might you expect routine bloodwork to reveal? elevated levels of calcitonin elevated levels of parathyroid hormone decreased levels of insulin decreased levels of creatinine elevated levels of troponin
3,4	Gross and microscopic anatomy – male and female reproductive systems/urinary tract including nephron histology	Identify the major cells, tissues, and organs of the urinary system including the nephron, and male and female reproductive systems.	Knowledge, Comprehension	1,2,7	Identify the region where a majority of glomeruli are located.  A B C D	Identify the portion of the nephron in which most reabsorption takes place.  A B C D E

5,6	Gross and microscopic anatomy – digestive system/endocrine system/respiratory system	Identify the major cells, tissues, and organs of the digestive and respiratory systems.	Knowledge, Comprehension	1,2,7	Identify the following organ.  Gallbladder Liver Large intestine Small intestine Pancreas	Identify the following structure.  Adrenal gland Thyroid gland Thymus land Submandibular gland Pituitary gland
7,8	Gross and microscopic anatomy – the heart and blood vessels	Identify the major blood vessels and structures of the heart.	Knowledge, Comprehension	1,2,7	Identify this structure on the heart.  Bicuspid (mitral) valve Aortic semilunar valve Pulmonary semilunar valve Tricuspid valve Left ventricle	Identify this vessel.  Ulnar artery Brachial artery Radial artery Subscapular artery Brachiocephalic artery
9,10	Survey of body systems	Describe the major functions of the cardiovascular system.	Knowledge, Comprehension	1,2	The greatest influence to increase blood flow is decreased blood viscosity decreased vessel radius decreased vessel length increased vessel radius reduced cardiac output	Most of the fluid filtered from capillaries is reabsorbed back into the last half (venule end) of the capillary. The force for this reabsorption primarily comes from the presence of globulins antibodies fibrinogen thrombin albumin
11,12	Survey of body systems	Identify the source, target, and role of major	Knowledge, Comprehension	1,2	The secretion of progesterone stimulates secretory activity in the	The target tissue for prolactin is/are the thyroid gland

		hormones.			glands of the breast contraction of uterine muscles secretory activity of the uterine endometrium development of the female secondary sexual characteristics loss of the srtatum functionalis of the uterine endometrium	adrenal medulla mammary glands gonads adrenal cortex
13,14	Survey of body systems	Describe the function of the cells, tissues, and organs of the lymphatic system and immune system.	Knowledge, Comprehension	1,2	In response to an antigenic challenge, B cells differentiate into plasma cells and release antibodies activate helper T cells differentiate into cytotoxic T cells increase their phagocytic properties differentiate into T cells and release interferon	The lymphatic organ/structure that gradually decreases in size after puberty and also becomes increasingly fibrous is the spleen liver thoracic duct tonsil thymus
15,16	Survey of body systems	Describe the function of the cells, tissues, and organs of the digestive system and related accessory structures and organs.	Knowledge, Comprehension	1,2	Chemical digestion of proteins begins in the mouth duodenum colon stomach appendix	Bile is manufactured by cells in the liver gallbladder small intestine stomach esophagus
17,18	Survey of body systems	Describe the function of the organs and structures of the respiratory system.	Knowledge, Comprehension	1,2	If a person has a vital capacity of 4000 ml, an expiratory reserve volume of 1100 ml, and an inspiratory reserve volume of 2500 ml, the tidal volume is ___ ml. 250 400 1000 1400 1500	The vital centers of the brain responsible for control of respiration, as well a heart rate and blood vessel diameter are located in the thalamus cerebrum cerebellum hypothalamus medulla oblongata
19,20	Survey of body systems	Describe the function of the organs and structures of the urinary system.	Knowledge, Comprehension	1,2	An increase in glomerular blood pressure will cause urine production to cease not affect urine production increase the glomerular filtration rate	The mechanism that establishes the medullary osmotic gradient depends most on the permeability properties of the loop of Henle (nephron loop) glomerular filtration membrane

					decrease the glomerular filtration rate increase calcium reabsorption	glomerulus distal convoluted tubule glomerular capsule
21,22	Regulation of water intake and output/Chemical composition of major fluid compartments/Buffer systems	Explain the role of organ systems in maintaining chemical, fluid, and acid/base balance.	Knowledge, Comprehension	1,2	Potassium, magnesium, and phosphate ions are the predominant electrolytes in plasma interstitial fluid intracellular fluid blood lymph	Water moves in and out of body compartments by what mechanism? osmosis facilitated diffusion primary active transport secondary active transport carrier-mediated transport
23		Attitude Question			Do you feel as though the information covered on this test was addressed in class/lab? Yes No	

These goals form the unifying foundation for all topics in anatomy and physiology and are to be emphasized throughout Anatomy and Physiology I and II. They are directly linked to the learning outcomes written by the HAPS Curriculum & Instruction Committee:

1. Develop a vocabulary of appropriate terminology to effectively communicate information related to anatomy and physiology.
2. Recognize the anatomical structures and explain the physiological functions of body systems.
3. Recognize and explain the principle of homeostasis and the use of feedback loops to control physiological systems in the human body.
4. Use anatomical knowledge to predict physiological consequences, and use knowledge of function to predict the features of anatomical structures.
5. Recognize and explain the interrelationships within and between anatomical and physiological systems of the human body.
6. Synthesize ideas to make a connection between knowledge of anatomy and physiology and real-world situations, including healthy lifestyle decisions and homeostatic imbalances.
7. Demonstrate laboratory procedures used to examine anatomical structures and evaluate physiological functions of each organ system.
8. Interpret graphs of anatomical and physiological data.

Appendix F

Electronic Consent Form Posted in Blackboard

A Quantitative Assessment and Comparison of Conceptual Learning in
Online and Classroom-Instructed Anatomy and Physiology

My name is Joel Humphrey and I am a Professor at (College), a State University of New York (SUNY) Institution, and also a Ph.D. student in the Department of College Science Teaching at Syracuse University. (College) is conducting research for the State University of New York comparing student performance in our online and on-campus Anatomy and Physiology classes. I am also using the data collected as part of a dissertation project at Syracuse University.

This research will be performed by comparing performance on pre- and post-tests by online students with the performance on the same exams of on-campus students. The pre- and post-tests will each take approximately 20 minutes to complete. In addition to the pre- and post-tests, in order to learn more about the students who take Anatomy and Physiology at (College), there is a survey that contains standard demographic questions. The survey will take approximately 5 minutes of your time to complete.

Information on individual students will not be used, and instead pooled data on test performance from both types of class modality (online and on-campus) will be compared. I will assign a number to your responses, and only I, Joel Humphrey, will have the key to indicate which number belongs to which participant. I, as the researcher, will be the only person to have access to your names, and any and all data used in the SUNY research report or SU Ph.D. dissertation will be confidential. Since the data will be pooled together, no individual identifiers will be used in any report generated from this data. The data that are collected will be kept on a secure, password-protected file on a password-protected desktop computer in a private office at (College).

I am inviting you to participate in this study. Your participation in this study is voluntary. Involvement in the study is based on your participation in the course and completion of the demographic survey and pre- and post-tests. The benefit of this research to you is that you will be helping to ascertain differences between online and on-campus learning in Anatomy and Physiology. The results of this research can impact the number and type of sections offered by the college and transfer policies. In addition, investigating and comparing the use of technology of an online medium (Blackboard Learning Management System) in Anatomy and Physiology will help advance understanding of teaching the subject. There are no direct benefits to you by taking part in this study.

Whenever one works with the internet, there is always the risk of compromising privacy, confidentiality, and/or anonymity. Your confidentiality will be maintained to the degree permitted by the technology being used. It is important for you to understand that no guarantees can be made regarding the interception of data sent via the internet by third parties. If you do not want to take part, you have the right to refuse to take part, without penalty. If you decide to take part and later no longer wish to continue, you have the right to withdraw from the study at any time, without penalty. You must be 18 years of age or older to participate in this research study.

If you have any questions, concerns, or complaints about the research, please contact Joel Humphrey via email at Humphrey@(college)-cc.edu, or via phone at 315.294.XXXX. If you have any questions about your rights as a research participant, you have questions, concerns, or complaints that you wish to address to someone other than the investigator, or if you cannot reach the investigator, you may contact Dr. XXXXX, Vice President of Academic Affairs at (College), at 315.255.XXXX, Extension XXX.

By continuing (clicking on the survey link) you are signifying your consent to participate, acknowledgement of your risks of participating, and agreement with the statement: "All of my questions have been answered, I am 18 years of age or older, and I agree to participate in this research study."

Please print a copy of this consent form for your records.

Table 1. Comparison of Sections, Pedagogical and Assessment Strategies, and Offerings in Online and On-Campus Courses.

	Online A&P	*On-Campus A&P*
Course Delivery Method	Asynchronous online (Blackboard)	Synchronous face-to-face, with some sections web-enhanced (notes and review material were provided in Blackboard or a similar website)
Number of Sections Included in Study	Fall: A&PI: 4 A&PII: 2 Spring: A&PI: 6 A&PII: 4 Total: 16	Fall: A&PI: 6 A&PII: 1 Spring: A&PI: 3 A&PII: 7 Total: 17
Instructional Activities	Narrative Lectures Multimedia Resources Discussion Boards Textbook Readings	PowerPoint Lectures Multimedia Resources Classroom interactions/discussions Textbook Readings
Assessment Modes	Timed exams in Blackboard; Timed practicals in *MasteringAandP*	Semi-timed in-class exams (constrained by the length of the class period); Timed practicals in lab
Topics Covered	A&PI: Chapters 1-14 A&PII: Chapters 15-26	A&PI: Chapters 1-14 A&PII: Chapters 15-26
Number of Assessments	9 Exams covering lecture content; 3 Lab Practicals consisting of identification questions from virtual dissections; 1 Cumulative Final Exam	(Ranges are provided as the number varied depending on Instructor) 0-5 Quizzes; 3-5 Exams covering lecture content; 1-3 Lab Practicals consisting of identification questions from pig or cat dissections and human models
Lab Structure	Virtual experimentation (*PhysioEx*); Virtual Dissection (*Practice Anatomy Lab)*	Pig or Cat dissection, human models 6 Sections supplemented lab dissections/activities with online experimentation (*PhysioEx*) completed in-class (0% of class conducted virtually)
Class Capacity	25 per section	24-31 per section

Table 2. Response Rate by Group.

	ONLINE PARTICIPANT (RESPONSE RATE)	ON-CAMPUS PARTICIPANT (RESPONSE RATE)	ONLINE SECTIONS USED/OFFERED	ON-CAMPUS SECTIONS USED/OFFERED
A&P I	120 (55%)	110 (58%)	10/12	9/13
A&P II	59 (47%)	108 (65%)	6/9	8/11
TOTAL	179 (52%)	218 (62%)	16/21	17/24

Table 3. Characteristics of Student Populations in the Online and On-Campus Groups.

Characteristic	Value	On-campus (Control) (n=218) Mean ± SD	Online (Experimental) (n=179) Mean ± SD	On-campus (Control) n(%)	Online (Experimental) n(%)	*t*	*p*	CI	N
Age (years)		24.13 ± 8.51	28.78 ± 8.62			5.36	<0.001	2.94, 6.34	395
Gender	Female			187 (86)	153 (85)				340
	Male			30 (14)	26 (15)				56
Blackboard Experience	Yes			146 (67)	103 (58)				249
	No			72 (33)	76 (42)				148
GPA		3.28 ± 0.53	3.3 ± 0.46			0.31	>0.05	-0.90, 0.13	339
Prior Science Coursework (# of classes)		1.76 ± 1.37	2.51 ± 2.19			4.43	<0.001	0.53, 1.38	397
Prior Online Courses (# of classes)		1.11 ± 1.52	2.45 ± 1.89						335
Race	White			212 (97)	144 (80)				356
	Other			6 (3)	35 (20)				41
Work Hours	0			33 (15)	22 (12)				55
	1-10			19 (9)	17 (10)				36
	11-20			43 (20)	11 (6)				54
	21-30			74 (34)	22 (12)				96
	31-40			33 (15)	66 (37)				99
	41+			16 (7)	41 (23)				57

Table 4. Operationalization of Constructs for Statistical Analyses.

	Construct	Empirical Measurement
Dependent Variable	Conceptual Learning/Mastery of A&P Learning Outcomes	Pre-test/Post-test change score
Independent Variables	Aptitude/Effort	Self-reported most recent numerical GPA
	Age	Self-reported chronological age
	Sex/Gender	Self-reported multiple choice answer selection; 3 levels of items/options: male, female, transgender
	Race/Ethnicity	Self-reported 2-part multiple choice answer selections; 6 levels of items/options
	Experience/Familiarity/Comfort with Blackboard Learning Management Platform/Technology	Self-reported multiple choice answer selection regarding Blackboard use prior to current semester; 2 levels of items/options: yes, no
	Experience/Familiarity with Online Coursework/Technology	Self-reported multiple choice answer selection to number of previous online courses prior to current semester; 6 levels of items/options: 0, 1, 2, 3, 4, 5 or more
	Background in Science	Self-reported number of completed biology courses
	Non-Academic Time Commitments/Employment Obligations	Self-reported multiple choice answer selection to range of employment hours/week; 5 levels of items/options: 0-10, 11-20, 21-30, 31-40, 41 or more

Table 5. Descriptive Statistics and Paired Samples t-tests Summary For Each Class By Modality.

Class/Delivery Format (N)	Pre-test Range	Post-test Range	Pre-test Mean (SEM)	Post-test Mean (SEM)	Mean Change (SD)	*t(df)*	*p*	95% CI	*d*
A&PI On-campus (N=110)	2-16	2-21	7.45 (0.25)	12.45 (0.36)	-5.00 (3.61)	14.51 (109)	<0.001	-5.68, -4.32	2.78
A&PI Online (N=120)	0-17	5-22	9.04 (0.28)	12.78 (0.39)	-3.73 (3.70)	11.05 (119)	<0.001	-4.40, -3.06	2.03
A&PII On-campus (N=108)	3-13	3-21	8.18 (0.21)	11.82 (0.34)	-3.65 (3.49)	10.88 (107)	<0.001	-4.31, -2.98	2.10
A&PII Online (N=59)	0-19	2-20	9.95 (0.51)	13.27 (0.49)	-3.32 (3.59)	7.10 (58)	<0.001	-4.26, -2.39	1.86

SEM = standard error of the mean (calculated as $SD/\sqrt{n}$); SD = standard deviation of change score; df = degrees of freedom; *d* = Cohen's *d* effect size

Table 6. Omnibus Step-wise Regression Analysis Summary (N = 335) For the Independent Variables (GPA, Previous Online Courses, Age, Gender, Previous Biology Coursework, Work Hours, Previous Blackboard Experience, Race) Predicting the Dependent Variable (Change Score).

Variable	ß	SEß	*t (df=332)*	*p*	*d*	CI	R^2 Change
Step 1							
GPA	1.77	0.40	4.43	< 0.001	0.49	0.98, 2.56	0.06
Step 2							
GPA	1.78	0.40	4.50	< 0.001	0.49	1.00, 2.56	
Previous Online Courses	-0.29	0.10	-2.86	< 0.01	0.31	-0.51, -0.89	0.02
Excluded Variables							
Age	0.04		0.70	0.49			
Gender	0.04		0.70	0.49			
Prior Bio Courses	0.01		0.02	0.98			
Work Hours	-0.002		-0.04	0.97			
Prior Blackboard Experience	-0.09		-1.62	0.11			
Race	0.08		1.44	0.15			
Total: ***F(2,332) = 14.10,*** ***p < 0.001, R^2 = 0.08***							

Table 7. Online Step-wise Regression Analysis Summary (N = 148) For the Independent Variables (GPA, Previous Online Courses, Age, Gender, Previous Biology Coursework, Work Hours, Previous Blackboard Experience, Race) Predicting the Dependent Variable (Change Score).

Variable	ß	SEß	*t (df=146)*	*p*	*d*	CI	R^2 Change
Step 1							
GPA	0.30	0.64	3.81	< 0.001	0.63	1.18,3.72	0.09
Excluded Variables							
Previous Online Courses	-0.12		-1.55	0.12			
Age	0.07		0.89	0.37			
Gender	0.02		0.22	0.83			
Prior Bio Courses	0.01		0.17	0.87			
Work Hours	0.11		1.37	0.17			
Prior Blackboard Experience	-0.14		-1.77	0.08			
Race	0.07		0.84	0.40			
Total: $F(1,146) = 14.50$, $p < 0.001$, $R^2 = 0.09$							

**** Second step unnecessary***

Table 8. On-campus Step-wise Regression Analysis Summary (N = 186) For the Independent Variables (GPA, Previous Online Courses, Age, Gender, Previous Biology Coursework, Work Hours, Previous Blackboard Experience, Race) Predicting the Dependent Variable (Change Score).

Variable	**ß**	**SEß**	***t (df=184)***	***p***	***d***	**CI**	**R^2 Change**
Step 1							
GPA	0.19	0.50	2.57	< 0.01	0.38	0.30, 2.27	0.03
Step 2							
GPA	0.18	0.50	2.44	< 0.05	0.36	0.23, 2.19	
Work Hours	-0.15	0.16	-2.06	< 0.05	0.30	-0.65, -0.01	0.02
Excluded Variables							
Age	-0.02		-0.32	0.75			
Gender	0.03		0.46	0.65			
Prior Bio Courses	-0.01		-0.10	0.92			
Previous Online Courses	-0.07		-0.88	0.38			
Prior Blackboard Experience	-0.09		-1.31	0.10			
Race	0.08		1.12	0.26			
Total: ***$F(2, 184) = 5.48$,*** ***$p < 0.01$, $R^2 = 0.06$***							

Table 9. Frequency Distribution and Relative Frequencies of Assigned Letter Grades in Relation to Learning Modality.

	On-campus		**Online**	
Final Letter Grade	**N**	**%**	**N**	**%**
A	45	20.6	63	35.2
A-	27	12.4	26	14.5
B+	23	10.6	17	9.5
B	35	16.1	30	16.8
B-	18	8.3	8	4.5
C+	10	4.6	12	6.6
C	20	9.2	10	5.6
C-	19	8.7	2	1.1
D+	6	2.6	2	1.1
D	6	2.6	2	1.1
D-	5	2.3	0	0
F	2	1	6	3.4
W	2	1	1	0.6
Total	**218**	**100**	**179**	**100**

Chi-square = 26.15, df = 12, p = 0.01

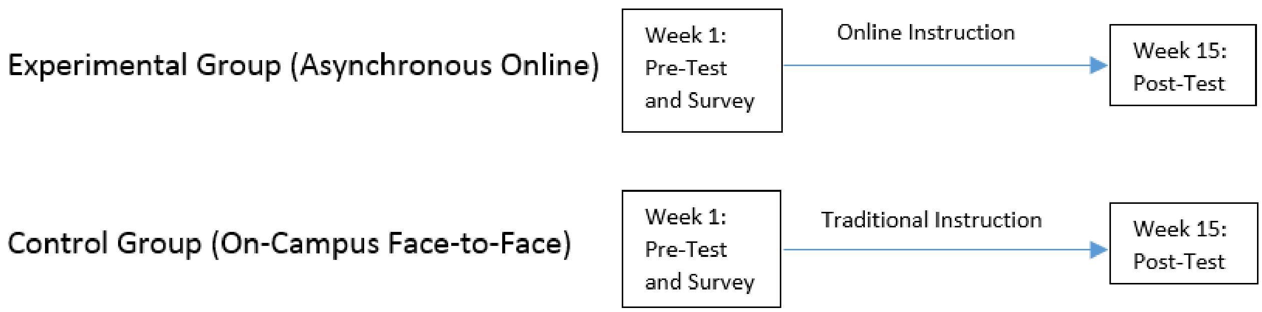
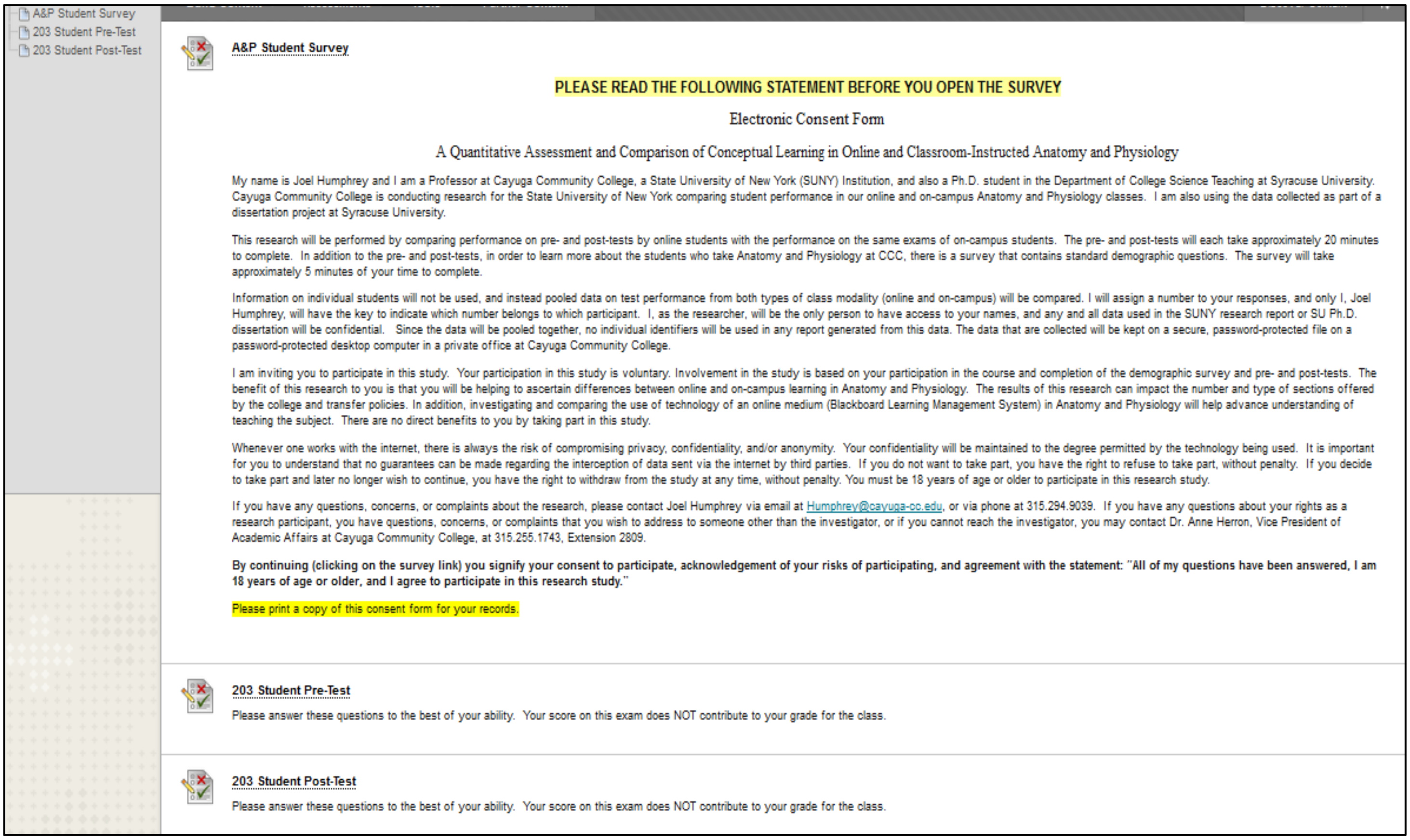


Figure 1. Schematic Representation of Quasi-experimental Design. Students self-selected into one of two course modalities, online (treatment) or on-campus (control). During week 1, students completed a pre-test and a demographic survey. During week 15, students completed a post-test.



A&P Student Survey
203 Student Pre-Test
203 Student Post-Test

A&P Student Survey

PLEASE READ THE FOLLOWING STATEMENT BEFORE YOU OPEN THE SURVEY

Electronic Consent Form

A Quantitative Assessment and Comparison of Conceptual Learning in Online and Classroom-Instructed Anatomy and Physiology

My name is Joel Humphrey and I am a Professor at Cayuga Community College, a State University of New York (SUNY) Institution, and also a Ph.D. student in the Department of College Science Teaching at Syracuse University. Cayuga Community College is conducting research for the State University of New York comparing student performance in our online and on-campus Anatomy and Physiology classes. I am also using the data collected as part of a dissertation project at Syracuse University.

This research will be performed by comparing performance on pre- and post-tests by online students with the performance on the same exams of on-campus students. The pre- and post-tests will each take approximately 20 minutes to complete. In addition to the pre- and post-tests, in order to learn more about the students who take Anatomy and Physiology at CCC, there is a survey that contains standard demographic questions. The survey will take approximately 5 minutes of your time to complete.

Information on individual students will not be used, and instead pooled data on test performance from both types of class modality (online and on-campus) will be compared. I will assign a number to your responses, and only I, Joel Humphrey, will have the key to indicate which number belongs to which participant. I, as the researcher, will be the only person to have access to your names, and any and all data used in the SUNY research report or SU Ph.D. dissertation will be confidential. Since the data will be pooled together, no individual identifiers will be used in any report generated from this data. The data that are collected will be kept on a secure, password-protected file on a password-protected desktop computer in a private office at Cayuga Community College.

I am inviting you to participate in this study. Your participation in this study is voluntary. Involvement in the study is based on your participation in the course and completion of the demographic survey and pre- and post-tests. The benefit of this research to you is that you will be helping to ascertain differences between online and on-campus learning in Anatomy and Physiology. The results of this research can impact the number and type of sections offered by the college and transfer policies. In addition, investigating and comparing the use of technology of an online medium (Blackboard Learning Management System) in Anatomy and Physiology will help advance understanding of teaching the subject. There are no direct benefits to you by taking part in this study.

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If you have any questions, concerns, or complaints about the research, please contact Joel Humphrey via email at Humphrey@cayuga-cc.edu, or via phone at 315.294.9039. If you have any questions about your rights as a research participant, you have questions, concerns, or complaints that you wish to address to someone other than the investigator, or if you cannot reach the investigator, you may contact Dr. Anne Herron, Vice President of Academic Affairs at Cayuga Community College, at 315.255.1743, Extension 2809.

By continuing (clicking on the survey link) you signify your consent to participate, acknowledgement of your risks of participating, and agreement with the statement: "All of my questions have been answered, I am 18 years of age or older, and I agree to participate in this research study."

Please print a copy of this consent form for your records.

203 Student Pre-Test

Please answer these questions to the best of your ability. Your score on this exam does NOT contribute to your grade for the class.

203 Student Post-Test

Please answer these questions to the best of your ability. Your score on this exam does NOT contribute to your grade for the class.

Figure 2. Assessment Folder as Posted in Blackboard Learning Management System.

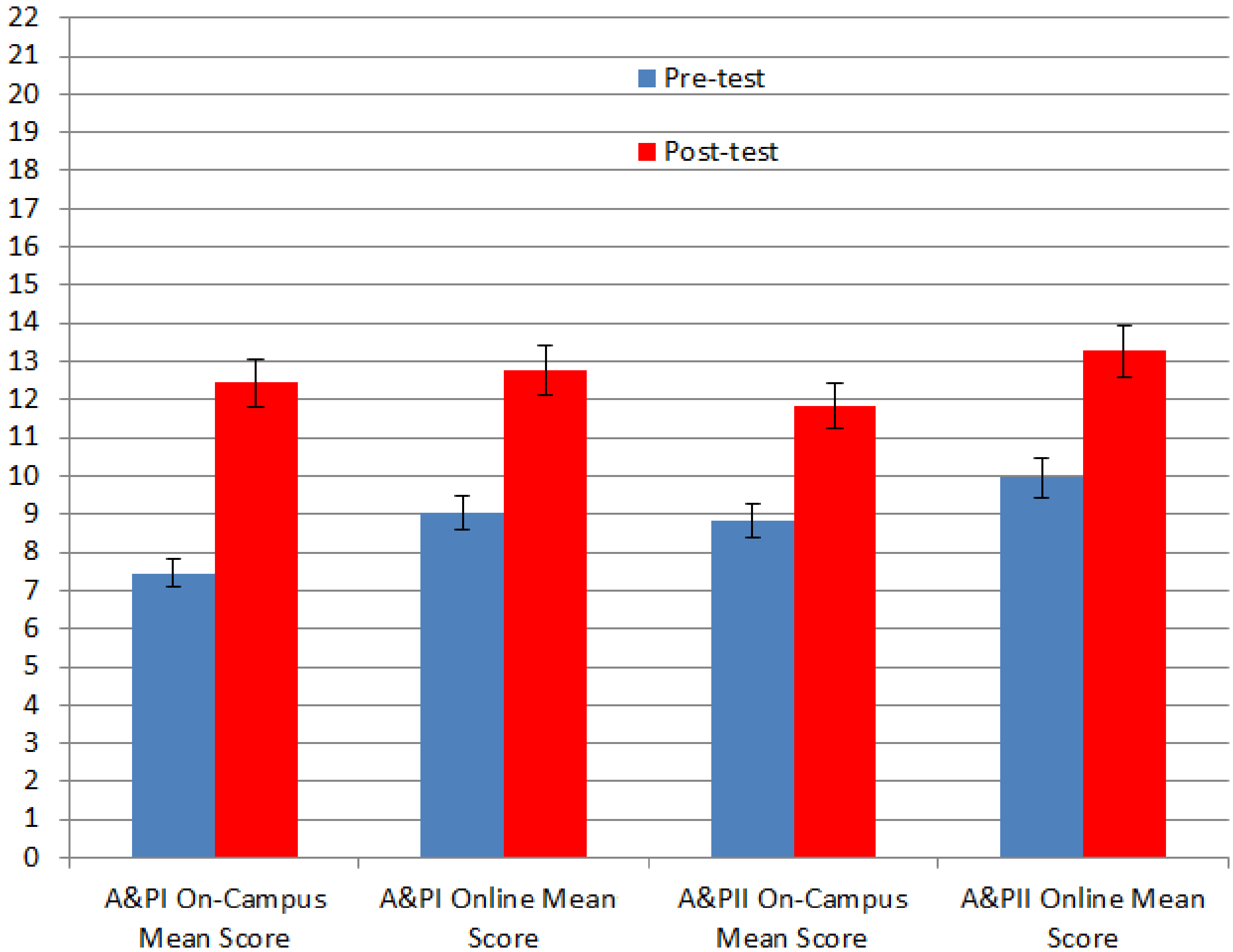

Figure 3. Pre-/Post-Test Means Shown Across Course and Instructional Modality. Error bars indicate 95% confidence intervals. A&PI online n = 120, A&PII online n = 59, A&PI on-campus n = 110, A&PII on-campus n = 108.

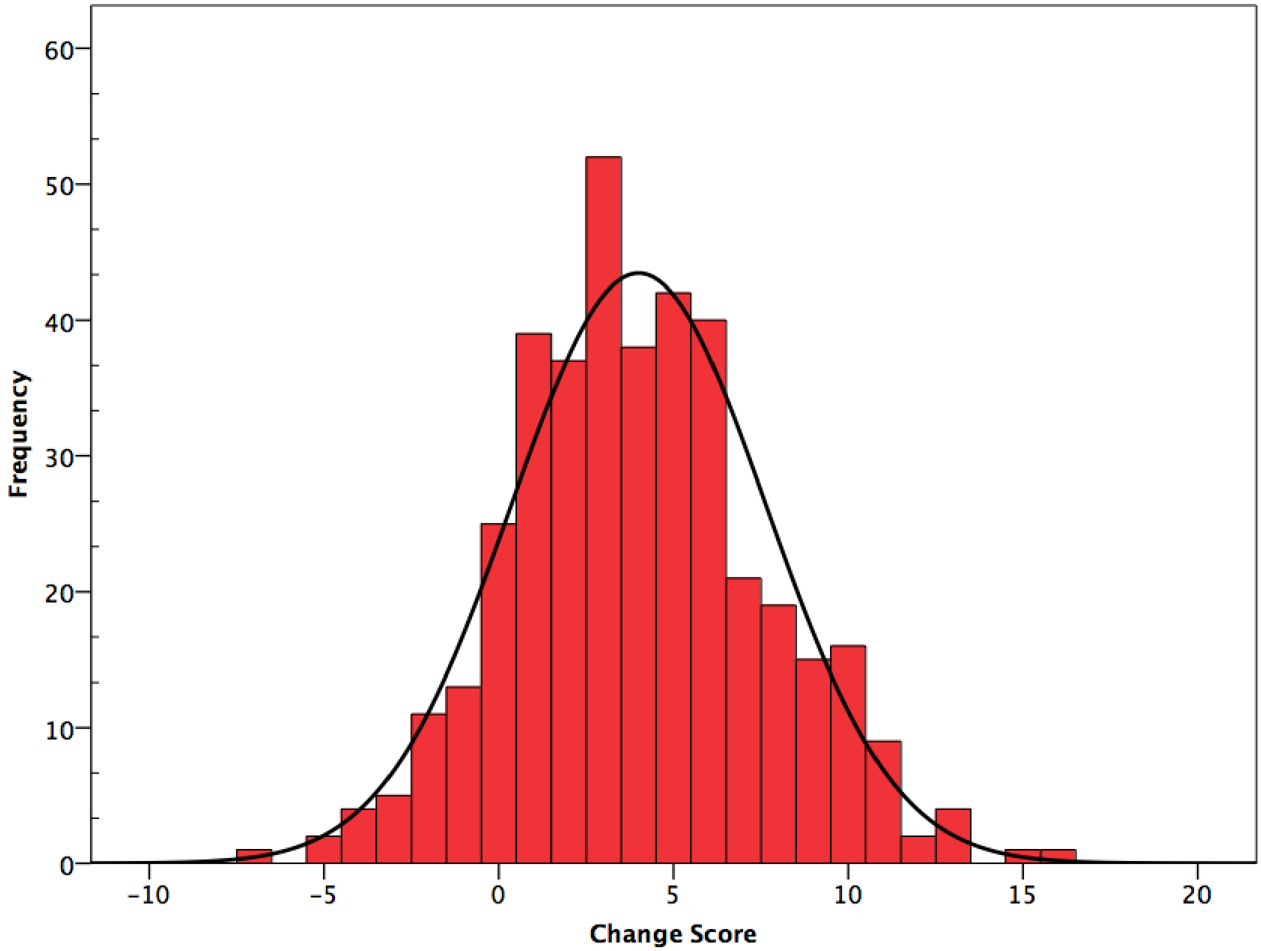

Figure 4. Overall Distribution of Change Scores Across Both Modalities. The data represent a normal distribution of change scores. Change scores were calculated by subtracting the pre-test score from the post-test score. Mean = 4, standard deviation = 3.645, N=397.

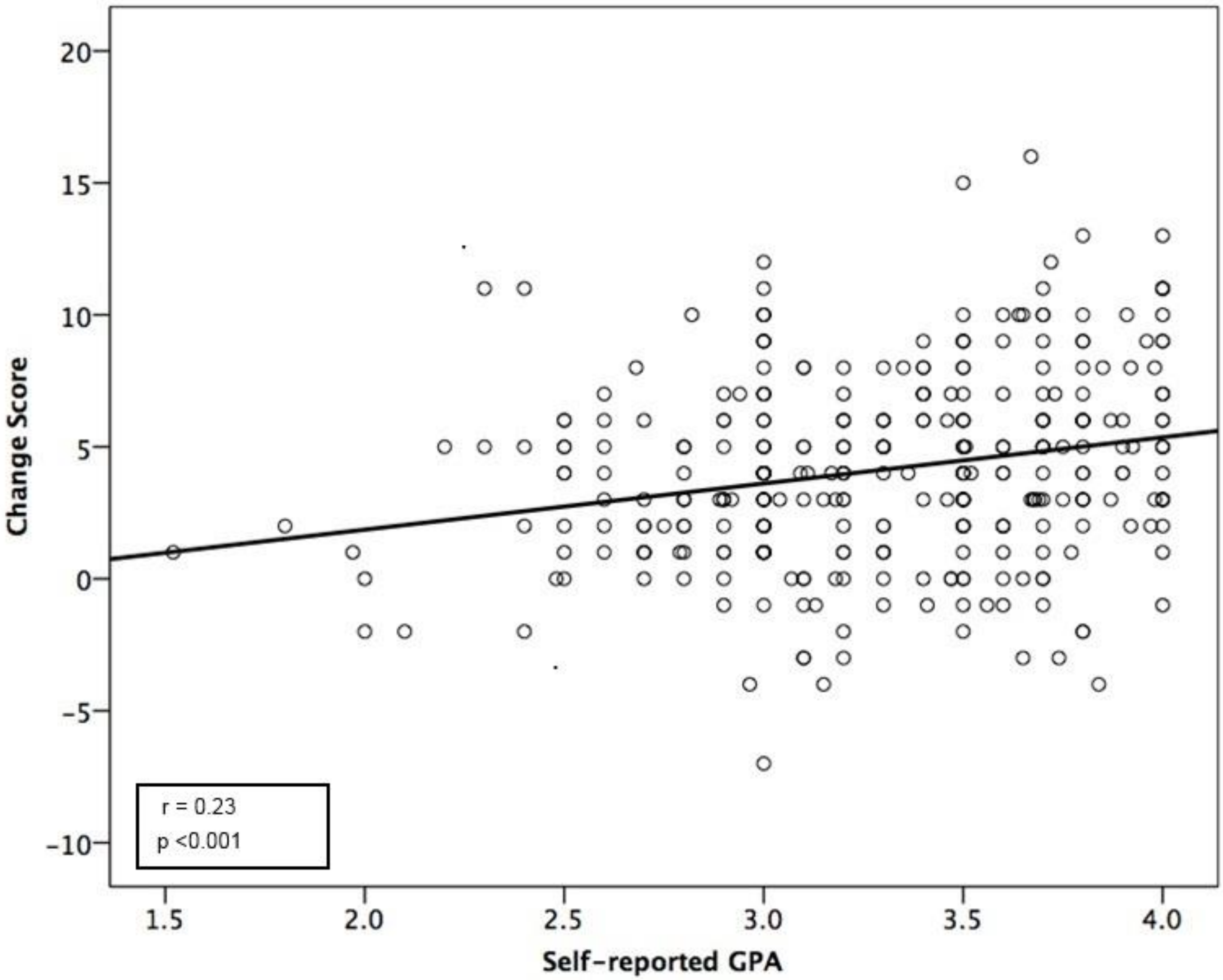

Figure 5. The Relationship Between Change Score and GPA Within Combined Learning Modalities. Student learning, as measured by change from pre- to post-test assessment, is significantly positively correlated with GPA. The value of r indicated in the figure (0.23), is Pearson's correlation coefficient for the two variables, N=339.

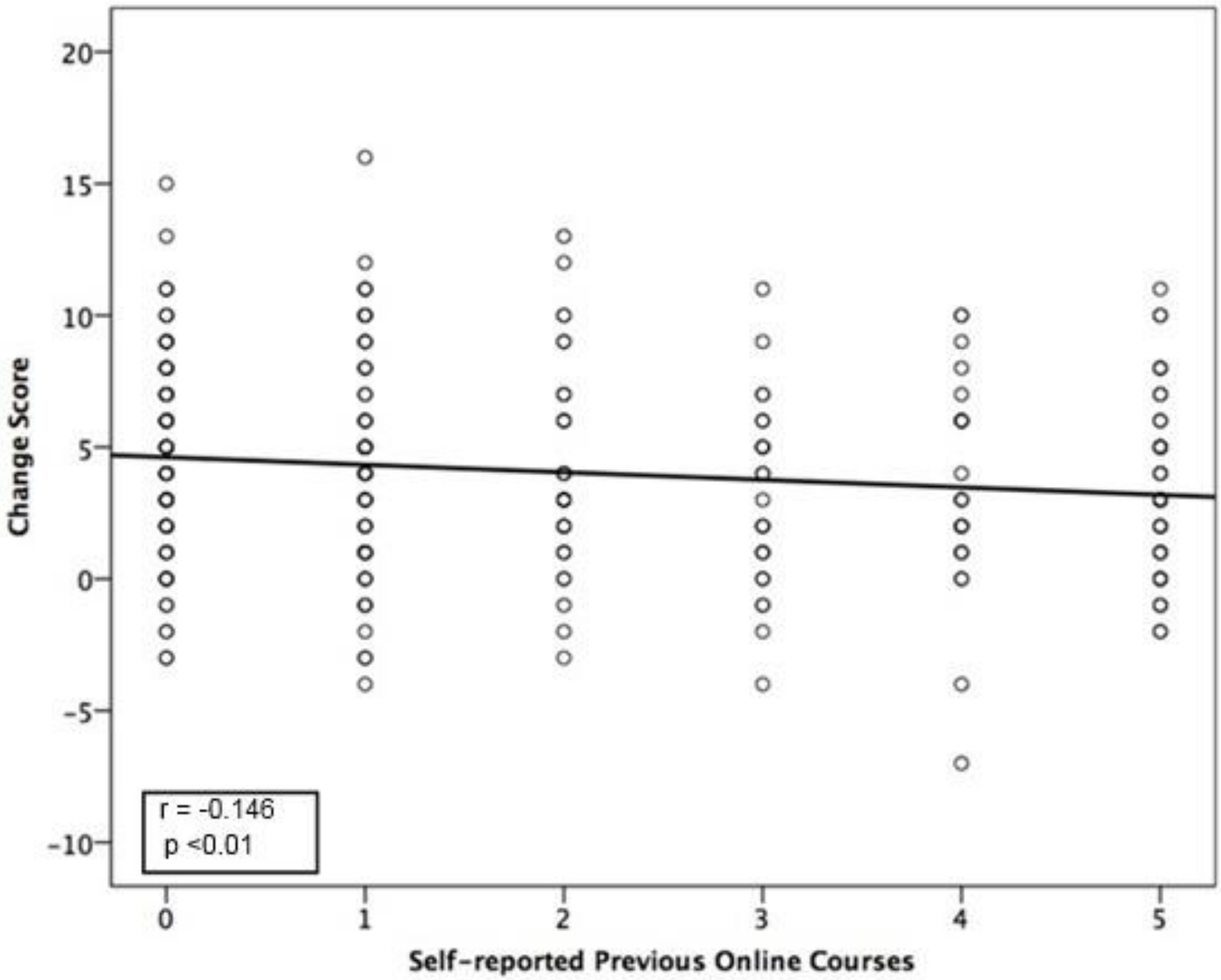

Figure 6. The Relationship Between Change Score and Students' Previous Online Course Experience Within Combined Learning Modalities. Student learning, as measured by change from pre- to post-test assessment, is significantly negatively correlated with the number of online courses students previously completed. The value of r indicated in the figure (-0.146), is Pearson's correlation coefficient for the two variables, N=335.

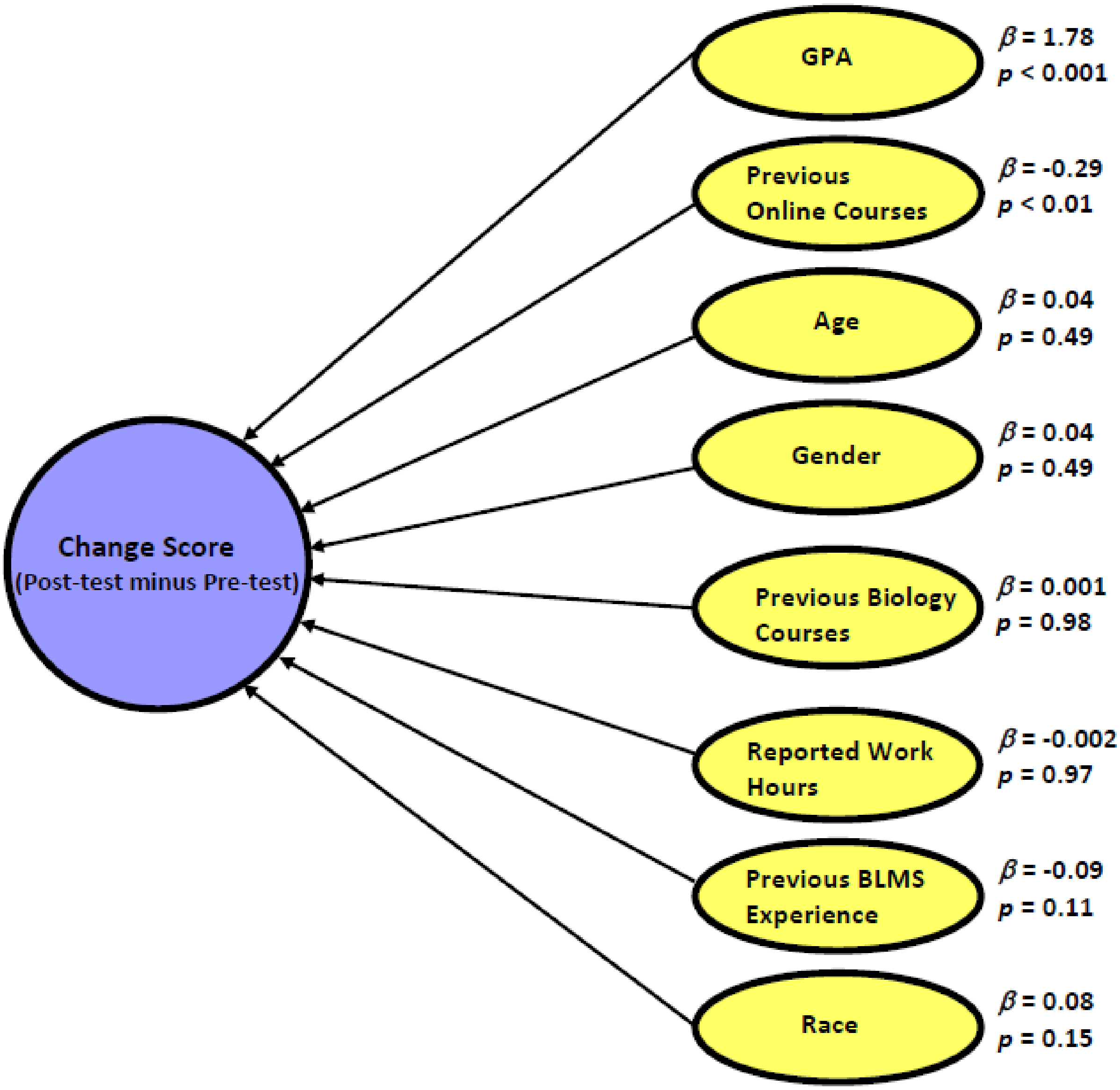

Figure 7. Regression Model for Influence of Characteristic Learner Variables on Change Score.

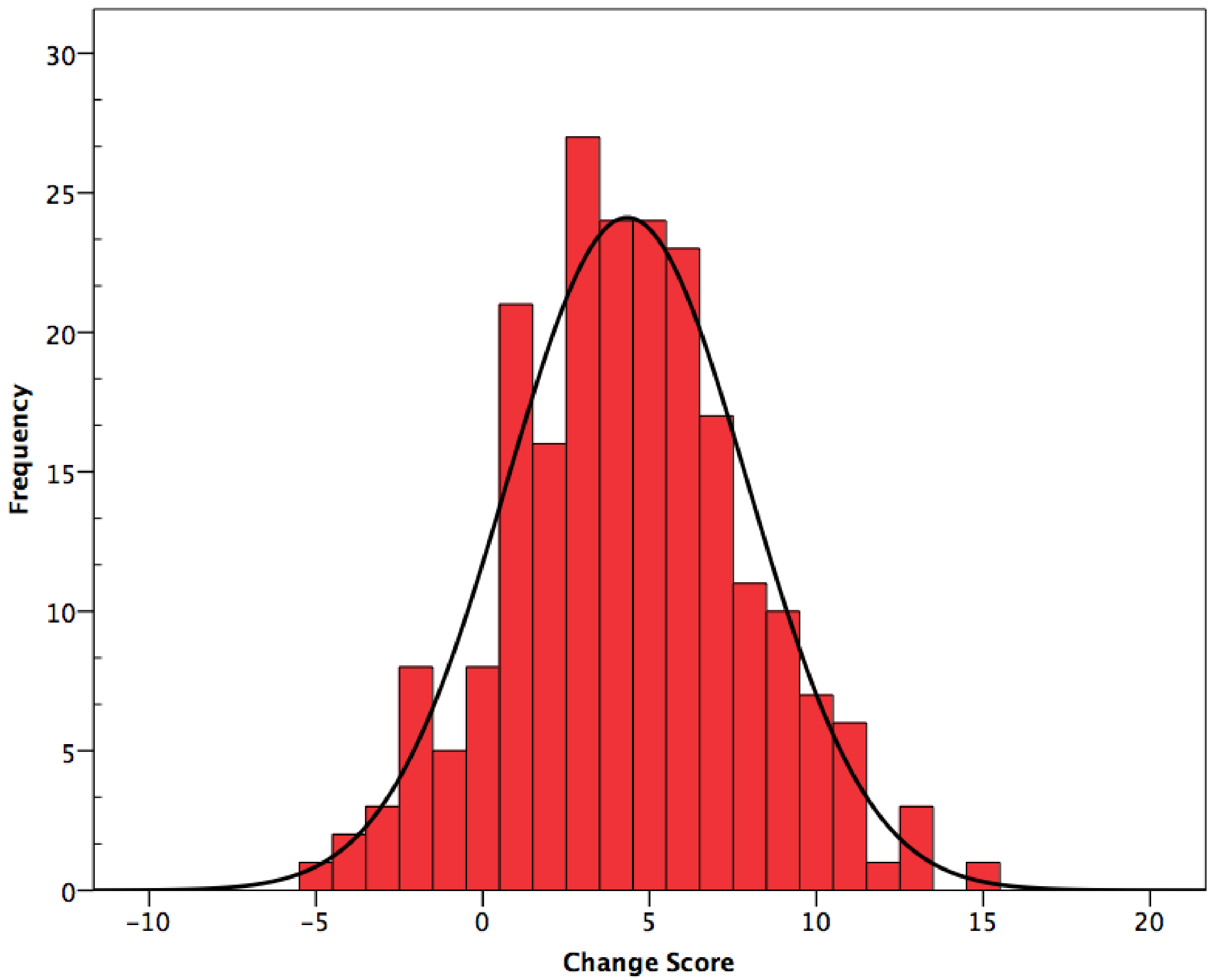

Figure 8. Distribution of Change Scores of On-campus Group. The data represent a normal distribution of change scores. Change scores were calculated by subtracting the pre-test score from the post-test score, N=218.

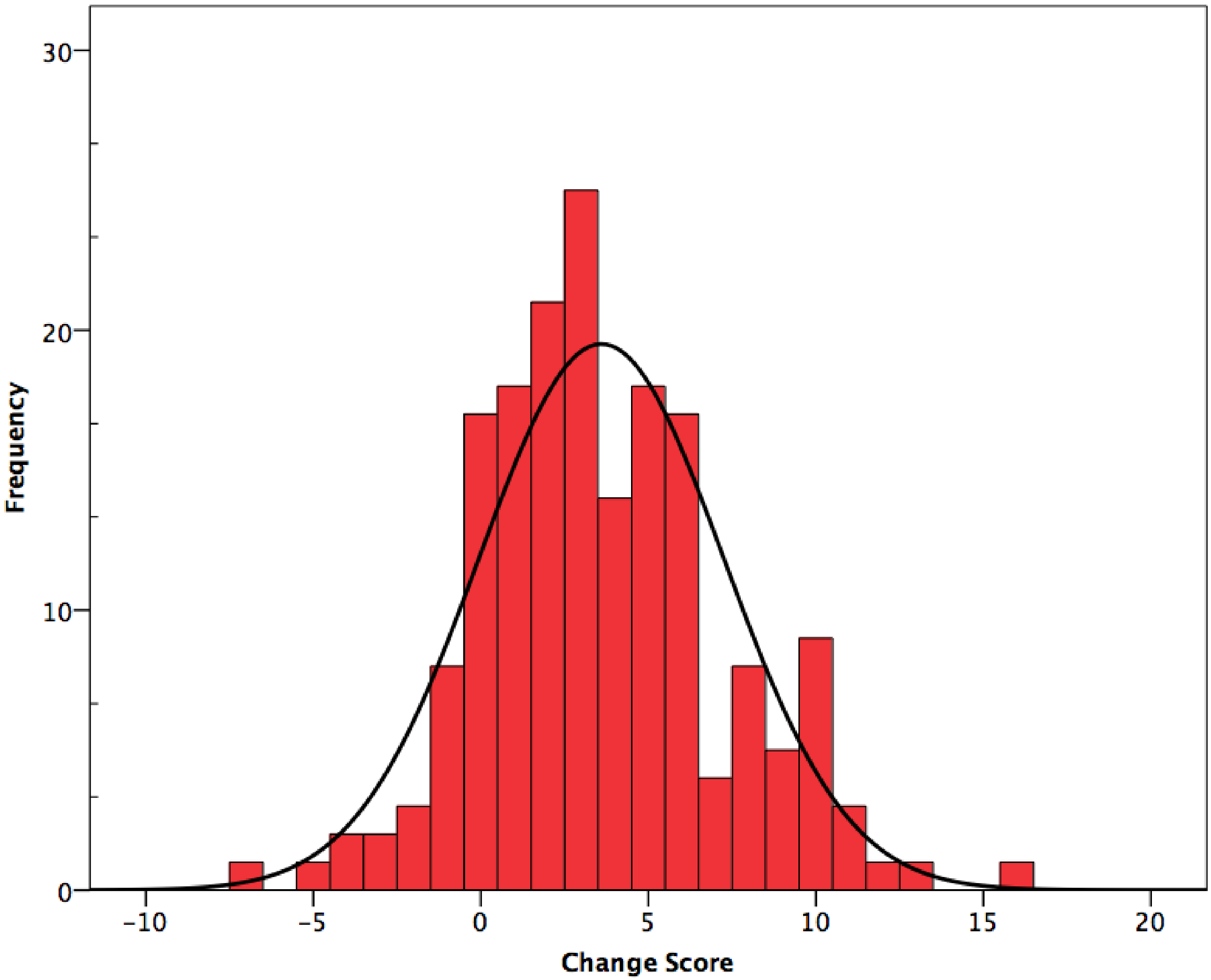

Figure 9. Distribution of Change Scores of Online Group. The data represent a normal distribution of change scores. Change scores were calculated by subtracting the pre-test score from the post-test score, N=179.

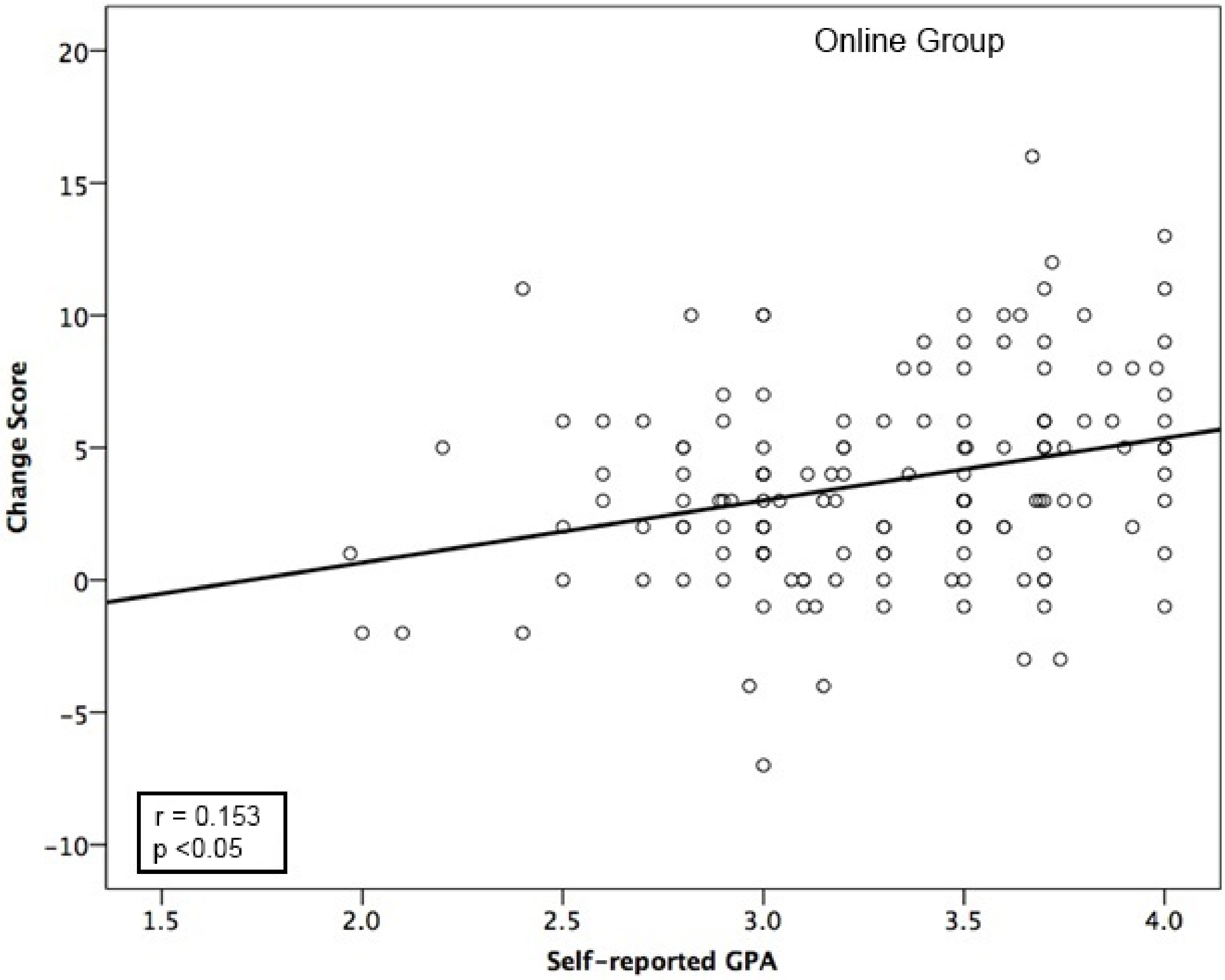

Figure 10. The Relationship Between Change Score and GPA in the Online Sections. Student learning, as measured by change from pre- to post-test assessment, is significantly positively correlated with students' self-reported GPA. The value of r indicated in the figure (0.153), is Pearson's correlation coefficient for the two variables, N=148.

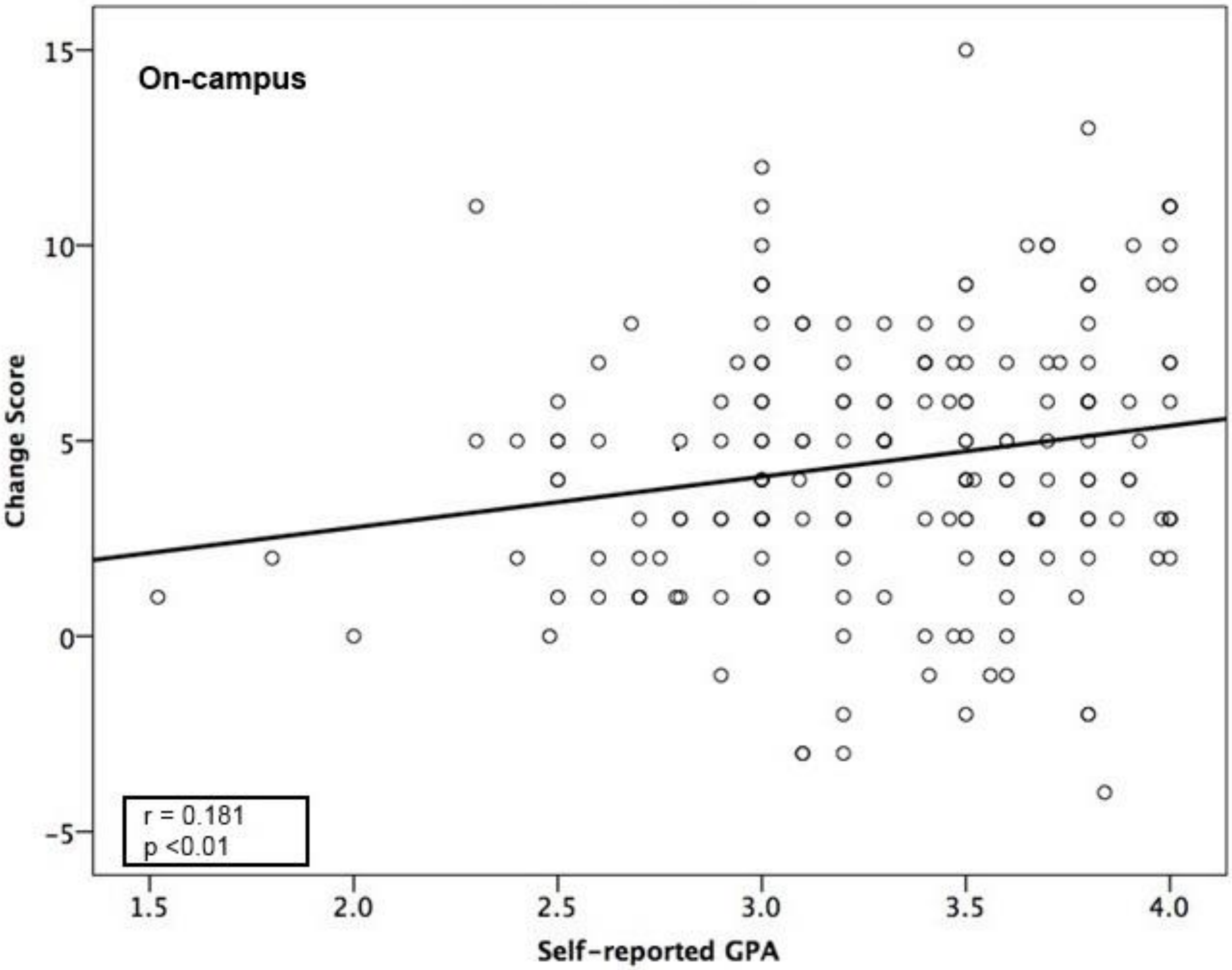

Figure 11. The Relationship Between Change Score and GPA in the On-campus Sections. Student learning, as measured by change from pre- to post-test assessment, is significantly positively correlated with students' self-reported GPA. The value of r indicated in the figure (0.181), is Pearson's correlation coefficient for the two variables, N=187.

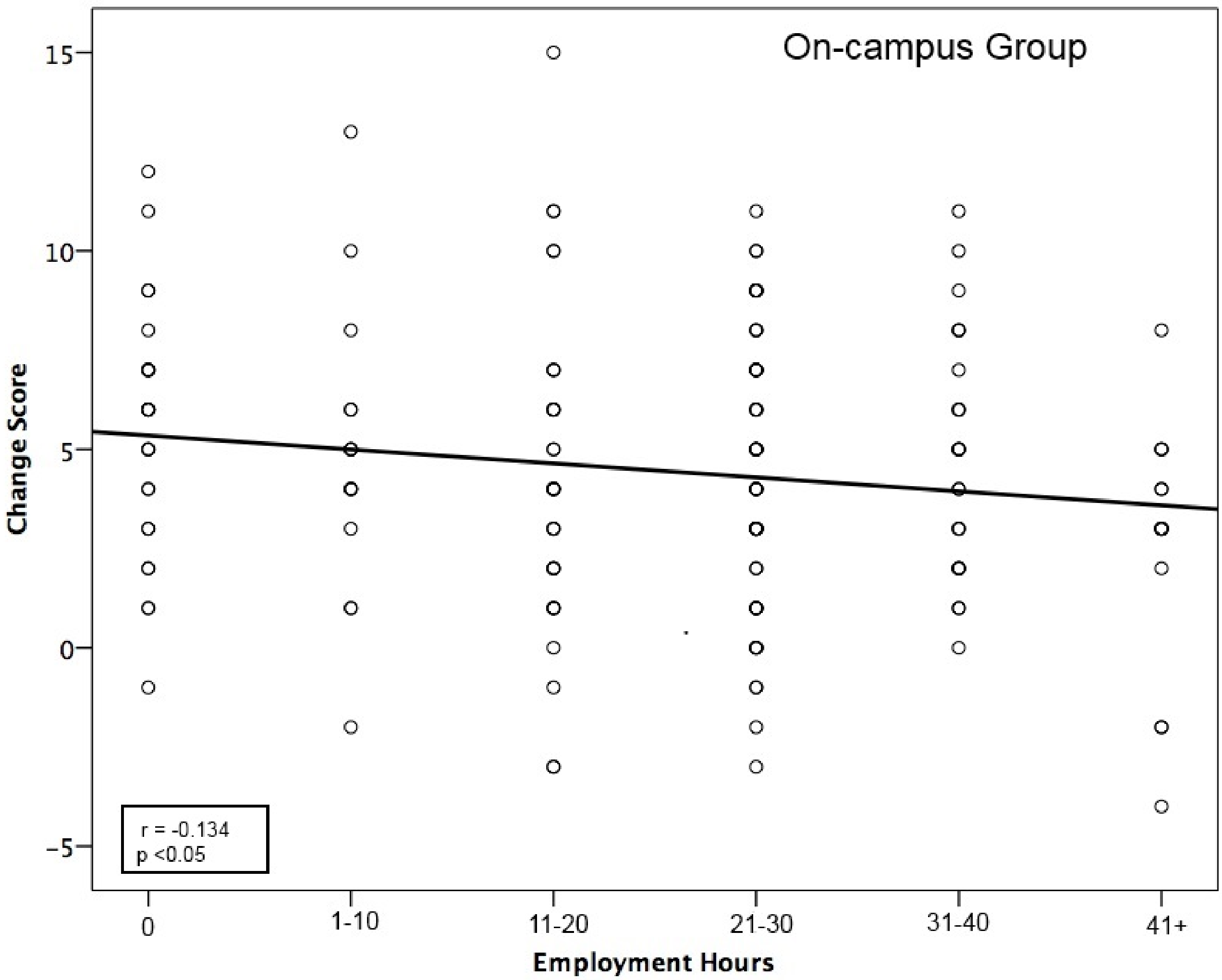

Figure 12. The Relationship Between Change Score and Employment Hours in the On-campus Sections. Student learning, as measured by change from pre- to post-test assessment, is significantly negatively correlated with students' hours of employment. The value of r indicated in the figure (-0.134), is Pearson's correlation coefficient for the two variables, N=187.

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Curriculum Vitae

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EDUCATION

Doctor of Philosophy in College Science Teaching, 2016
College of Arts and Sciences, Syracuse University, Syracuse, NY

Master of Science in Pharmaceutical Science: Forensic Science, DNA and Serology, 2006
College of Pharmacy, University of Florida, Gainesville, NY

Master of Arts in Biology, Evolution and Ecology, 2002
Department of Biological Sciences, Binghamton University, Binghamton, NY

Bachelor of Science in Environmental and Forest Biology, 1999
State University of New York College of Environmental Science and Forestry, Syracuse, NY

PRESENTATONS AND PUBLICATIONS

Humphrey, J.Y. (2009). *Assessing Student Learning Outcomes*. Presented at Assessment Day, Cayuga Community College, Auburn, NY.

Humphrey, R.J. & Humphrey, J.Y. (2009). *Developing Students' Understanding of Evolution in an Inquiry-Based Versus Traditional Science Classroom*. Presented at the Annual Association for Science Teacher Education Annual Conference, Hartford, CT.

Humphrey, J.Y. & Noll, L.K. (2005). *New Tricks For Old Dogs: Unleash The Power of "U".* Presented at the Annual Institute of Community College Development Successful Teaching Conference, Ithaca, NY.

Yager, J.M. (2002). *Comparative analysis of the sphenopalatine nerve and foramen in New World hystricognath rodents*. Master's Thesis, Binghamton University.

RELEVANT PROFESSIONAL EXPERIENCE

Professor, Cayuga Community College, Fulton/Auburn, NY, 2003-Present
Courses: Anatomy & Physiology I & II, Principles of Biology I & II, Forensic Science, Basic Nutrition, Essentials of Biology, Human Biology, Human Genetics, Genetics, Honors Courses, Online Courses, Accelerated Courses, Linked/Learning Communities

Adjunct Instructor, SUNY Cortland, Cortland, NY. 2002-2003
Courses: Principles of Biology I & II, Anatomy and Physiology I & II

Laboratory Instructor, SUNY Cortland, Cortland, NY, 2002-2003
Courses: Anatomy and Physiology I & II, Zoology, Mammalian Physiology

Laboratory Instructor, Elmira College, Elmira, NY, 2002
Courses: Anatomy & Physiology II, Animal Physiology

Graduate Teaching Assistant, Binghamton University, Binghamton, NY, 2000-2001
Courses: Anatomy & Physiology I, Organisms & Populations, General Biology Laboratory

Undergraduate Teaching Assistant, SUNY Environmental Science and Forestry, Syracuse, NY, 1997

PROFESSIONAL DISTINCTIONS/HONORS

SUNY Chancellor's Award for Teaching Excellence
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