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

An Evidence-Based Report Prepared for SUNY

Researcher and Author:

Joel Yager Humphrey
Professor of Biology, Cayuga Community College

December 2015
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EXECUTIVE SUMMARY

Background: 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.

Methodology: 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 multivariate regression model was used to assess the influence of learner variables on the knowledge-based assessment outcomes. An Analysis of Covariance (ANCOVA) was used to examine the effect of course modality on learning.

Results:
- Both online and on-campus participants significantly improved their performance on the post-test.
- There were no significant differences in learning gains between the online and on-campus groups.
- GPA significantly predicted performance on the learning assessment for the online treatment group.
- GPA and the number of employment hours significantly predicted performance on the learning assessment for the on-campus control group.

Conclusions: The results of this study support previous research regarding online learning in other disciplines. 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. It is anticipated that online biology courses will continue to contribute 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 implications for SUNY and higher education institutions regarding research and support of online courses in the natural
sciences, and further exploration of the potentials of such courses to attract and retain students. Distance education via online courses can be a powerful method to combat historical barriers preventing equal access to education, while at the same time produce learning outcomes on par with those of traditional classroom settings. As such, the education monopoly that has been historically held by traditional, physical classroom environments may soon expire.

Recommendations:

- SUNY and their affiliated institutions should continue to support research on learning in online biology courses.
- SUNY and their affiliated institutions should support online biology courses as a viable alternative to traditional classroom-instructed courses.
- SUNY’s seamless Transfer Path guidelines and biology course transfer policies should not be restrictive by modality – online biology lab courses should transfer in the same way online courses in other disciplines transfer.
- Administrators and pedagogues should employ this and other evidence-based data when making considerations regarding how online biology courses are incorporated into curricula, when they are offered, and if they are acceptable for transfer.
- Administrators and pedagogues should employ this and other evidence-based data to determine how the benefits of online biology courses can be utilized in higher education to reach, attract, and retain students, as well as sustain STEM programs.
CHAPTER 1: INTRODUCTION AND BACKGROUND

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 is 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) most of whom are community college students. 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. The growth of online learning has been quite significant over the past decade, most prominently over the past few years; therefore, studies have focused on whether online and traditional on-site courses are equivalent in terms of student performance and experience. Published articles cite 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). A large number of recent empirical studies comparing online instruction with traditional face-to-face instruction in various disciplines have found that online students perform as well as, 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., Abdullahi, 2011; 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 50 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, 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 in support 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 over a decade (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, and may be able to mirror the face-to-face experience in many ways. National Instrument’s LabVIEW system design is a commercially available software system that allows remote instrumentation control and 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 CourseSmart, and McGraw Hill’s Connect). In addition, 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 work 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. 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 - they perceive online courses as inferior to conventional face-to-face instruction. Although the data are limited, a majority of studies in chemistry, physics, and biology 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 (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 labs are generally well received and perceived by students (e.g., Sauter, Uttal, Rapp, Downing & Jona, 2013; Somenerain, Akkaraju & Gharbaran, 2010).

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. It should 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.

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 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 considered a high risk for not attaining a degree were over-represented in the sample. They believe the data support ongoing investment into online learning as a form of access to a college degree.

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.

There is only a small body of literature regarding differences in learning in online versus traditional laboratories. Most of the (limited) research sheds a positive light on learning science in an online modality, and accordingly, some professional and educational organizations and societies support the use of technology-mediated instruction. For example, The Human Anatomy & Physiology Society, supports “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).
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.

**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).

**Purpose and Significance of the Study**

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 they are equivalent in terms of conceptual learning outcomes.

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. 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.

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 postsecondary 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 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 at the same time meet 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 addressed the following research questions:

1. **How does the effectiveness of fully-online instruction compare with that of traditional face-to-face classroom/lab instruction in terms of conceptual learning?**

2. **Do the subject variables that influence student learning in online versus traditional biology courses differ?**
Although online learning has been researched heavily in the last decade, there has not been widespread research efforts or focus on fully-online course experiences in postsecondary lab-based natural science courses, specifically biology – a finding that is concomitant with the lack of online science course offerings overall. Instead, most of the research has been conducted in K-12 classrooms or postsecondary 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. However, the research that does exist supports the development and implementation of online courses and virtual labs in postsecondary science courses, and affirms their utility.

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 are considered the most challenging courses among biology majors and health-service students (El-Sayed et al., 2012; Johnston, 2010). 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. Therefore these subjects require implementation of “innovative approaches” when possible (White & Sykes, 2012, p. 2). Although the research is limited, the data that exist for online, hybrid, and web-enhanced anatomy and physiology courses appear promising, as most studies in this arena indicate that students who are exposed to a technology-mediated component performed as well 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.

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 are generally perceived positively by students. Educators should not look to technology-based virtual learning environments as a panacea for education, but instead identify where and when it can and should be incorporated to facilitate learning. 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. Technological advances have changed the landscape of biology laboratories, yet there is no universal consensus on the efficacy of online biology courses. As a result of the increasing focus on online/virtual learning environments, in combination with pressure on institutions for a greater level of institutional accountability and assessment, research in this field is particularly urgent. The data generated from this present research can be used to help all college administrators, admissions counselors, and faculty make decisions regarding program and curriculum development, distance education offerings, global marketing strategies, and course transfer/acceptance – policy decisions that can have an enormous impact on students, both academically and financially.

**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. 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 considered in this study, and therefore the results of this study are not generalizable to learning in every capacity.

**Limitations**

Cayuga Community College (CCC) has an open enrollment policy, and therefore the site population may not be representative of the typical college/university population in the United States. CCC has a higher proportion of female students, nontraditional students, and students who require accommodations due to diagnosed/documentated learning disabilities. In addition, there is not substantial ethnic/racial diversity, as a large percentage of students at CCC identify as white (CCC College Catalog, 2015). 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-tests 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.

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. 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). An additional threat to internal validity deals with prior science coursework experience, as this may influence a student’s scores on one or both of the assessments. This, along with other group characteristics, was addressed by using regression analysis during the data analytic portion of this study. In a pre-/post-test design, regression to the mean is a threat to internal validity, however, a large sample size minimizes this threat. A power analysis was conducted in order to determine the appropriate sample size and protect against regression effects. The demographic questionnaire required students to self-report their GPA, which may result in response bias and inflated values, thereby impacting conclusions drawn from regression analyses.

**Ethical Considerations**

The protocols used in this research were approved by the Cayuga Community College Institutional Review Board (Appendix A). This study was conducted as part of a PhD dissertation project through Syracuse University and therefore the researcher also obtained approval from the Syracuse University Institutional Review Board (Appendix B).

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: METHODS AND PROCEDURES

Research Site

All data collection was conducted at Cayuga Community College (CCC), located in Central New York. CCC is a two-year liberal arts college that offers broad-based career and transfer-oriented curricula on a degree or certificate basis. Established in Auburn, NY (Cayuga County) in 1953, CCC is one of 64 SUNY institutions. In 1994, the college expanded its operations to Oswego County in the town of Fulton, NY, which achieved official Branch Campus status in 2006. Data collection for this research occurred at both the Fulton and Auburn Campuses. During the time of this study, the total number of students attending CCC was over 4000, with approximately half matriculated as full-time, approximately 2/3 female, approximately 80% white, and a median age of 23 (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.

Anatomy and Physiology I and II serve as mandatory requisites for completion of CCC’s Applied Science (A.S.) Health Concentrations - including medical imaging, respiratory therapy, radiation therapy, medical technology, physical therapy, chiropractic medicine, and cardiovascular perfusion. Articulation agreements with various schools in Central NY have been established, and a grade of C or better obtained at CCC 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 matriculated at CCC as well as colleges throughout Central NY.

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. 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 performed in a computer lab using PhysioEx software (Zao, Stabler, Smith, Lokuta & Griff, 2015).

CCC 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, CCC transitioned the content management platform to Angel, and then finally to BLMS in 2014. 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. The sample used 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 or Anatomy and Physiology II. Participants were sampled from courses that were instructed 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 19 A&PI sections and a total of 14 A&PII sections included in the study, with a total of 397 participants (N=179 in on-campus sections and N=218 in online sections). 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. During the timeframe of data collection, the sections were taught by ten adjunct faculty members and seven full-time faculty members.
Table 1. Comparison of Sections, Pedagogical and Assessment Strategies, and Offerings in Online and On-Campus Courses During the Terms of the Research Study.

<table>
<thead>
<tr>
<th>Course Delivery Method</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fully asynchronous online (Blackboard)</td>
<td>Synchronous face-to-face, with some sections web-enhanced (notes and review material were provided in Blackboard or a similar website)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Sections Included in Study</th>
<th>Fall: A&amp;PI: 4 A&amp;PII: 2</th>
<th>Fall: A&amp;PI: 6 A&amp;PII: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total: 16</td>
<td>Total: 17</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructional Activities</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrative Lectures</td>
<td></td>
<td>PowerPoint Lectures</td>
</tr>
<tr>
<td>Multimedia Resources</td>
<td></td>
<td>Multimedia Resources</td>
</tr>
<tr>
<td>Discussion Boards</td>
<td></td>
<td>Classroom interactions/discussions</td>
</tr>
<tr>
<td>Textbook Readings</td>
<td></td>
<td>Textbook Readings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment Modes</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timed exams in Blackboard; Timed practicals in <em>Mastering A&amp;PI</em></td>
<td>Semi-timed in-class exams (constrained by the length of the class period); Timed practicals in lab</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topics Covered</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Number of Assessments</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Exams covering lecture content; 3 Lab Practicals consisting of identification questions from virtual dissections; 1 Cumulative Final Exam</td>
<td>(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</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lab Structure</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual experimentation (<em>PhysioEx</em>); Virtual Dissection (<em>Practice Anatomy Lab</em>)</td>
<td>Pig or Cat dissection, human models 6 Sections supplemented lab dissections/activities with virtual experimentation (<em>PhysioEx</em>)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class Capacity</th>
<th>Online A&amp;P</th>
<th>On-Campus A&amp;P</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 per section</td>
<td>24-31 per section</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. Response Rate by Group. The online group response rate was 52% and the on-campus group response rate was 62%.

<table>
<thead>
<tr>
<th></th>
<th>Online Participant (response rate)</th>
<th>On-Campus Participant (response rate)</th>
<th>Online Sections Used/Offered</th>
<th>On-campus Sections Used/Offered</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;P I</td>
<td>117 (55%)</td>
<td>110 (58%)</td>
<td>10/12</td>
<td>9/13</td>
</tr>
<tr>
<td>A&amp;P II</td>
<td>59 (47%)</td>
<td>108 (65%)</td>
<td>6/9</td>
<td>8/11</td>
</tr>
<tr>
<td>Total</td>
<td>176 (52%)</td>
<td>221 (62%)</td>
<td>16/21</td>
<td>17/24</td>
</tr>
</tbody>
</table>

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 total of 341 females and 56 males). Most of the participants identified as white (351). 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 in on-campus sections and 29 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 BLMS, and 38% responded that they had no prior BLMS 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-\(\beta\)) set at 0.80 and \(\alpha\) 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.

Table 3. Characteristics of Student Populations in the Online and On-Campus Groups. A total of 397 students participated in the study, 86% identified as female, 88% identified as white, and ages ranged from 18-57, with an average age of 26 years. Most participants (90%) were using the course(s) as a prerequisite for admittance to a health science program or a nursing program, and 62% had prior experience using BLMS.
**Procedure, Treatment, and Instrument**

Participants in both groups (online and on-campus) were directed to an Assessment Folder in Blackboard (Figure 3), and required to complete an identical series of assessments - a demographic questionnaire, pre-test, and post-test (Appendices C, D, and E). The demographic questionnaire and pre- and post-tests were completed in and submitted in BLMS. 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. Other controlling/participant variables were analyzed to determine their effect, if any, on learning. A standardized battery of demographic information was collected from each subject, including age, gender, race/ethnicity, GPA, reason for taking the course, experience with Blackboard, previous science coursework, employment, and home institution.

*Figure 3. Assessment Folder Posted in Blackboard Learning Management System.*
Demographic data were collected using a 17-question survey instrument administered within seven days from the first class meeting. Survey questions were selected based on the assumptions that certain variables may influence and serve as predictors of student success, and therefore questions were designed to glean information regarding participants’ GPA, experience with BLMS, biology background, degree programs, and program/transfer intentions. In addition to the online demographic questionnaire, a knowledge-based test was administered to permit inferences about student course 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 4).

**Figure 4. Schematic Representation of Quasi-experimental Design.** Students self-selected into one of two course modalities, online (treatment) or on-campus (control). During week one, students completed a pre-test and a demographic survey. During week 15, students completed the post-test.

Experimental Group (Asynchronous Online)

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

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. Prior to their implementation, the tests were reviewed by two full-time faculty members for accuracy and subsequently field-tested on an independent group of anatomy and physiology students.

For A&PI, the pre- and post-assessments were the same for each course section for each term and course setting. For A&P II, 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. 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 was multiple choice format with 4-5 answer options. A pre-determined marking scheme was used, with a maximum score of 22 (each question was worth 1 point). The pre- and post-tests were automatically scored by BLMS upon submission. 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 BLMS 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 PI 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 allows students to look up answers). Group means and range of scores are presented in Table 4. The demographic survey did not have a time limit. After classes ended for each term, the scores from the pre- and post-tests were downloaded from BLMS. 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 BLMS experience, and prior online course experiences. 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 knowledge-based assessments. 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* ($H_0: \mu_1 = \mu_2$).

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 (Levene’s test, pre- and post-test linear relationship) and
homoscedasticity (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 ($\eta^2$) 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. 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 seven self-reported learner
variables of interest in the regression analysis included age, gender, GPA, prior experience with
BLMS, experience with online courses, previous science coursework, and employment
obligations. 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).
CHAPTER 3: RESULTS AND DISCUSSION OF FINDINGS

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, $p < 0.001$ (Figure 5 and Table 4).

Figure 5. Change Score Means Shown Across Course and Instructional Modality. Change scores are calculated by the difference on pre-test and post-test scores. Error bars indicate 95% confidence intervals. A&PI online $n = 117$, A&PII online $n = 59$, A&PI on-campus $n = 113$, A&PII on-campus $n = 108$. All groups showed significant difference between pre-test and post-test score at $p < 0.001$. 
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, $F(1,394) = 0.16, p > 0.05$. 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

---

**Table 4. Descriptive Statistics and Paired Samples t-tests Summary for Each Class by Modality.**

*All groups showed a significant difference between pre-test and post-test scores at $p < 0.001$.*

<table>
<thead>
<tr>
<th>Class/Delivery Format</th>
<th>Pre-test Range</th>
<th>Post-test Range</th>
<th>Pre-test Mean (SEM)</th>
<th>Post-test Mean (SEM)</th>
<th>$t$</th>
<th>$p$</th>
<th>95% CI</th>
<th>$d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;PI On-campus</td>
<td>2-16</td>
<td>2-21</td>
<td>7.45 (0.25)</td>
<td>12.45 (0.36)</td>
<td>14.51</td>
<td>&lt;0.001</td>
<td>-5.68, -4.32</td>
<td>2.78</td>
</tr>
<tr>
<td>A&amp;PI Online</td>
<td>0-17</td>
<td>5-22</td>
<td>9.04 (0.28)</td>
<td>12.78 (0.39)</td>
<td>11.05</td>
<td>&lt;0.001</td>
<td>-4.40, -3.06</td>
<td>2.03</td>
</tr>
<tr>
<td>A&amp;PII On-campus</td>
<td>3-13</td>
<td>3-21</td>
<td>8.18 (0.21)</td>
<td>11.82 (0.34)</td>
<td>10.88</td>
<td>&lt;0.001</td>
<td>-4.31, -2.98</td>
<td>2.10</td>
</tr>
<tr>
<td>A&amp;PII Online</td>
<td>0-19</td>
<td>2-20</td>
<td>9.95 (0.51)</td>
<td>13.27 (0.49)</td>
<td>7.10</td>
<td>&lt;0.001</td>
<td>-4.26, -2.39</td>
<td>1.86</td>
</tr>
</tbody>
</table>
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 (homogeneity of variance) 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 6.

**Figure 6. Overall Frequency 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 (maximum possible score=22) from the post-test score (maximum possible score=22). Mean = 4, standard deviation = 3.645, N=397.
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 was not an issue.

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 7 and 8). 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 5 and the regression model is depicted in Figure 9.

**Figure 7. 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.
Figure 8. 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.

Table 5. Step-wise Regression Analysis Summary (N = 335) For the Independent Variables (GPA, Previous Online Courses, Age, Gender, Prior Biology Coursework, Work Hours, Previous Blackboard Experience, Race) Predicting the Dependent Variable (Change Score). Only GPA and the number of online courses previously taken predicted performance on the learning assessment, p < 0.001. Other variables were therefore excluded from the final model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>SEβ</th>
<th>t</th>
<th>p</th>
<th>d</th>
<th>CI</th>
<th>R² Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td>1.77</td>
<td>0.40</td>
<td>4.43</td>
<td>&lt; 0.001</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPA</td>
<td>1.78</td>
<td>0.40</td>
<td>4.50</td>
<td>&lt; 0.001</td>
<td>0.49</td>
<td>1.00, 2.56</td>
<td>0.02</td>
</tr>
<tr>
<td>Previous Online Courses</td>
<td>-0.29</td>
<td>0.10</td>
<td>-2.86</td>
<td>&lt; 0.01</td>
<td>0.31</td>
<td>-0.51, -0.89</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Excluded Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.04</td>
<td>0.70</td>
<td>0.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>0.04</td>
<td>0.70</td>
<td>0.49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Bio Courses</td>
<td>0.01</td>
<td>0.02</td>
<td>0.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work Hours</td>
<td>-0.002</td>
<td>-0.04</td>
<td>0.97</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior Blackboard Experience</td>
<td>-0.09</td>
<td>-1.62</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td>0.08</td>
<td>1.44</td>
<td>0.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total $R^2 = 0.08, p < 0.001$
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 (homogeneity of variance) was reasonable and box plots suggested a relatively normal distributional shape (with no outliers) of the residuals.

Figure 10. 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 (maximum possible score=22) from the post-test score (maximum possible score=22).

Figure 11. 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 (maximum possible score=22) from the post-test score (maximum possible score=22).
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 12). 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 ($p > 0.05$).

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 13), and employment hours, $p < 0.05$ (Figure 14) 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 ($p > 0.05$).
Figure 12. 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.

Figure 13. 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.
Figure 14. 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.

Discussion

In order to determine if an online anatomy and physiology learning environment could promote learning gains on par with those in a traditional face-to-face learning environment, the current study analyzed 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. Learning gains, measured by the difference in scores on pre- and post-treatment measurements, 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 both modalities. This study replicated similar research comparing the learning outcomes of online and traditional courses in other disciplines, and the present findings are consonant with previous findings, and are not particularly surprising.

Few learner variables were found to predict performance in both the online and on-campus groups. It is not remarkable that GPA was found to be a predictor of success, 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, Boyles & Weaver, 2008); hence, students who had been previously successful were more likely to continue to be successful. This study used 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 online group was found to be negatively correlated with the number of online courses previously completed. 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., 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. Due to the paucity in the research on this topic, there are no studies that explore such variables in online anatomy and physiology courses (and therefore 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. On-campus students with less hours of employment per week demonstrated learning gains higher than those employed more hours per week. Previous studies have indicated that online students who worked between 1-10 hours per week had higher chances of success and completion (Simpson, 2006), however this study found no such inverse relationship. Therefore, the present findings suggest that the flexible nature of the online courses in this study may have accommodated students with rigorous employment demands to complete the assignments around their schedules, while the on-campus students were not afforded the same flexibility. Gender was not found to be a predictor, 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; Park & Choi, 2009; Price, 2006; Yukselturk & Bulut, 2009).
CHAPTER 4: CONCLUSIONS

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 by some faculty and administrators in higher education regarding the equivalency of learning in online classes, 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 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.

SUNY Transfer Paths and Open SUNY

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 many 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, 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(s) for colleges and universities that want to implement technology-based online learning into biology and health-related programs. This is particularly significant for SUNY institutions, as most are in the process of aligning their transfer programs with SUNY-wide Transfer Pathways.

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, and also contradict the evidence presented in this report. The Seamless Transfer Resolution states “seamless transfer permits students to complete a degree without duplicative effort or unnecessary costs” (p. 1). The requirements do not guarantee that online biology courses with a lab component are transferrable to other SUNY institutions, despite the courses being successfully completed at a SUNY institution. Adhering to this requirement could place students in these paths at an unnecessary disadvantage. Equally important, is that this requirement is not grounded in scholarly research. 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). This research provides evidence that students exposed to virtual/distance/online anatomy and physiology courses performed equivalently to their face-to-face counterparts. Therefore, removing online lab course restrictions from these Transfer Paths is recommended. Anecdotal evidence has been mounting for years, as a number of CCC’s nursing students have completed anatomy and physiology online, and in the last 5 years, CCC has experienced pass rates well above the national average on NCLEX exams (with pass rates of 97% or above). Now, this report provides empirical data regarding learning in online lab courses.

Recommendations and Future Research

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 the internet 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 allowing students 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 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 et al., 2005).

The results of this study are not definitive, as this study was executed using a quasi-experimental design that relied on voluntary participation. However, despite the limitations, this study provides valuable information, and at the least, 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. As there are few analogous research studies that analyze conceptual learning in fully online asynchronous anatomy and physiology courses, the results of this study cannot be compared with previous studies. Additional research on asynchronous online lab-based biology courses is needed, especially studies that explore both conceptual knowledge gains as well as acquisition of procedural operational 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.

It is recommended that CCC and SUNY continue to support research in and implementation of online science courses. Online learning will no doubt continue to change the tapestry of academic offerings and provide 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 online courses can be a powerful method to combat historical barriers preventing equal access to education. As online course platform technologies advance, and more institutions, faculty, and students embrace and utilize the potentials of online learning, its growth is expected to continue to accelerate across all disciplines and programs, including science. 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 information can be applied to assist institutions when making considerations regarding how these courses are implemented, when they are offered, if they are acceptable for transfer, and how their benefits can be utilized and enhanced to reach, attract, and retain students.
APPENDIX A: CCC IRB Approval Letter

AUBURN CAMPUS
197 Franklin Street, Auburn, New York 13021
Tel: (315) 255-1743  Fax: (315) 255-2117
www.cayuga-cc.edu

August 6, 2014

Professor Joel Humphrey
Cayuga Community College
11 River Glen Campus
Fulton, New York 13069

Dear Professor Humphrey:

I received the recommendation of Cayuga Community College’s Institutional Review Board to approve your study entitled, “Comparing the Effectiveness of Online and Face-to-Face Learning in Anatomy & Physiology.” This letter verifies my agreement with the IRB’s recommendation. I enthusiastically support your research regarding the effectiveness of asynchronous online learning environments in relation to traditional on campus or traditional face-to-face learning environments in anatomy and physiology.

I anticipate that you will provide Cayuga Community College with a report of your findings. We look forward to reading your study.

Sincerely,

Anne J. Herron, Ed.D.
Provost and Vice President of Academic Affairs

C: Carol Runge
   Director of Institutional Research and Planning
   Chair, Institutional Review Board
APPENDIX B: Syracuse University IRB 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 Croman, M.S.W.
Director

DEPT: Science Teaching, 112 Heroy

STUDENT: Joel Humphrey

Office of Research Integrity and Protections
121 Botine Hall, Syracuse, New York 13244-1200
(Phone) 315-443-3013 • (Fax) 315-443-9889
orip@syr.edu • www.orip.syr.edu

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APPENDIX C: Demographic Survey

1. Have you taken this course demographic survey previously in BIO 203 or BIO 204?
   - 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?
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?
   o From faculty/staff at the college I currently attend
   o From faculty/staff at the college I plan to attend
   o From the SLN (SUNY Learning Network) Website
   o Word of mouth - from someone who took the course or knew about it
   o Web search
   o 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?
   o 0
   o 1-10
   o 11-20
   o 21-30
   o 31-40
   o 41 or more

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

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

17. In what modality are you taking this course?
   o On-campus
   o Online
## APPENDIX D: A&P I Pre-/Post-Test and Linked Learning Outcomes

### A&PI Pre/Post Test

<table>
<thead>
<tr>
<th>Test Question Numbers</th>
<th>Topic(s) (Adapted from HAPS Guidelines)</th>
<th>Learning Outcome (Adapted from HAPS)</th>
<th>Cognitive Level(s) of Outcome</th>
<th>Fundamental Content Goal(s) Targeted</th>
<th>Question 1</th>
<th>Question 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2</td>
<td>Directional terms/Basic terminology</td>
<td>Describe the location of body organs, structures, cavities, regions, and planes using appropriate anatomical terminology.</td>
<td>Knowledge, Comprehension</td>
<td>1,2,5</td>
<td>The fingers are ____ to the elbow.</td>
<td>The ____ plane runs longitudinally and divides the body into right and left sides.</td>
</tr>
<tr>
<td>3,4</td>
<td>Intracellular organization of nucleus and cytoplasm/Organelles/Membrane structure and function</td>
<td>Describe the basic structure of a cell and cell membrane and the functions of its components.</td>
<td>Knowledge, Comprehension</td>
<td>1,2</td>
<td>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</td>
<td>This organelle is responsible for providing most of the ATP needed by the cell.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>simple diffusion</td>
<td>lysosome</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>membrane potential</td>
<td>smooth endoplasmic reticulum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>osmosis</td>
<td>mitochondria</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>facilitated reabsorption</td>
<td>ribosome</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>selective permeability</td>
<td>Golgi apparatus</td>
</tr>
<tr>
<td>5,6</td>
<td>Microscopic anatomy/Overview of histology and tissue types</td>
<td>Identify and contrast the general features of the four major tissue types.</td>
<td>Knowledge, Analysis</td>
<td>1,2</td>
<td>Identify the following tissue type.</td>
<td>Which type of epithelium covers the body and serves as protection for the body surface?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Smooth muscle</td>
<td>simple squamous</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Connective</td>
<td>stratified squamous</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Epithelial</td>
<td>transitional</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nervous</td>
<td>pseudostratified columnar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Skeletal muscle</td>
<td>cuboidal</td>
</tr>
<tr>
<td>7,8</td>
<td>Application of homeostatic mechanisms/ Predictions related to homeostatic imbalance, including disease states and disorders</td>
<td>Explain the types of integrated regulatory responses of different organ systems and how they relate to one another to maintain homeostasis.</td>
<td>Analysis, Application</td>
<td>1,2,3,4,5,6,8</td>
<td>If a person is injected with a toxin that blocks acetylcholine receptors, what symptom would you expect to observe in the patient?</td>
<td>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</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>loss of bone density</td>
<td>negative feedback because the response amplifies the change.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>muscle paralysis</td>
<td>positive feedback because the response amplifies the change.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>loss of vision</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>elevated blood glucose levels</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>muscle spasticity and tetanus</td>
<td></td>
</tr>
<tr>
<td>9,10</td>
<td>Gross and microscopic anatomy - nervous system and special senses</td>
<td>Identify the location and describe the structure and function of the major anatomical structures of the eye, ear, brain, and spinal cord.</td>
<td>Knowledge, Comprehension</td>
<td>Identify the structure that contains photoreceptors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11,12</td>
<td>Gross and microscopic anatomy – location and function of bones and bone markings</td>
<td>Identify individual bones and bone markings and describe their function.</td>
<td>Knowledge, Comprehension</td>
<td>Identify the following bone structure.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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.**

**Identify “D” in the following image.**

- A
- B
- C
- D

**Knowledge, Comprehension**

- 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.

**Identify the structure that contains photoreceptors.**

- A
- B
- C
- D

**Identify the following bone structure.**

- Medial condyle
- Lateral epicondyle
- Head
- Greater trochanter

**Lacuna Perforating canal Periosteum Lamella**
<table>
<thead>
<tr>
<th>Table Entries</th>
<th>Topic</th>
<th>Task</th>
<th>Required Knowledge</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>13,14</td>
<td>Gross and microscopic anatomy - location and function of the major skeletal muscles</td>
<td>Identify the location and function of the major skeletal muscles.</td>
<td>Knowledge, Comprehension 1,2,7</td>
<td>Identify the following structure. Muscle fiber Fascicle Perimysium Myofibril Sartorius Gastrocnemius Brachioradialis Rectus femoris</td>
</tr>
<tr>
<td>15,16</td>
<td>Survey of body systems</td>
<td>Describe the function of the organs and accessory structures of the integumentary system.</td>
<td>Knowledge, Comprehension 1,2</td>
<td>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</td>
</tr>
<tr>
<td>17,18</td>
<td>Survey of body systems/Classification, structure, and function of joints</td>
<td>Describe the function of the organs, structures, and articulations of the skeletal system.</td>
<td>Knowledge, Comprehension 1,2</td>
<td>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</td>
</tr>
<tr>
<td>19,20</td>
<td>Survey of body systems</td>
<td>Describe the function of the organs and structures of the</td>
<td>Knowledge, Comprehension 1,2</td>
<td>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</td>
</tr>
</tbody>
</table>
muscular system.

Contraction
Latent
Refractory
Relaxation
Tetany

expose active sites on actin 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

Describe the function of the organs and structures of the nervous system.

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.

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

Survey of body systems

Knowledge, Comprehension

1,2

21,22

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.

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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:
## APPENDIX E: A&P II Pre-/Post-Test and Linked Learning Outcomes

### A&P II Pre/Post Test

<table>
<thead>
<tr>
<th>Test Question Numbers</th>
<th>Topic(s) (Adapted from HAPs)</th>
<th>Learning Outcome (Adapted from HAPS)</th>
<th>Cognitive Level(s) of Outcome</th>
<th>Fundamental Content Goal(s) Targeted</th>
<th>Question 1</th>
<th>Question 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2</td>
<td>Application of homeostatic mechanisms/ Predictions related to homeostatic imbalance, including disease states and disorders</td>
<td>Explain the types of integrated regulatory responses of different organ systems and how they relate to one another to maintain homeostasis.</td>
<td>Analysis, Application</td>
<td>1,2,3,4,5,6,8</td>
<td>A patient was in a car accident and has suffered from 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</td>
<td>A patient is losing bone density and is found to have hypercalcemia. 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</td>
</tr>
<tr>
<td>3,4</td>
<td>Gross and microscopic anatomy – male and female reproductive systems/urinary tract including nephron histology</td>
<td>Identify the major cells, tissues, and organs of the urinary system including the nephron, and male and female reproductive systems.</td>
<td>Knowledge, Comprehension</td>
<td>1,2,7</td>
<td>Identify the region where a majority of glomeruli are located.</td>
<td>Identify the portion of the nephron in which most reabsorption takes place.</td>
</tr>
<tr>
<td>5,6</td>
<td>Gross and microscopic anatomy – digestive system/endocrine system/respiratory system</td>
<td>Identify the major cells, tissues, and organs of the digestive and respiratory systems.</td>
<td>Knowledge, Comprehension</td>
<td>1,2,7</td>
<td>Identify the following organ.</td>
<td>Gallbladder, Liver, Large intestine, Small intestine, Pancreas</td>
</tr>
<tr>
<td>7,8</td>
<td>Gross and microscopic anatomy – the heart and blood vessels</td>
<td>Identify the major blood vessels and structures of the heart.</td>
<td>Knowledge, Comprehension</td>
<td>1,2,7</td>
<td>Identify this structure on the heart.</td>
<td>Bicuspid (mitral) valve, Aortic semilunar valve, Pulmonary semilunar valve, Tricuspid valve, Left ventricle</td>
</tr>
<tr>
<td>9,10</td>
<td>Survey of body systems</td>
<td>Describe the major functions of the cardiovascular system.</td>
<td>Knowledge, Comprehension</td>
<td>1,2</td>
<td>The greatest influence to increase blood flow is decreased blood viscosity, decreased vessel radius, increased vessel length, reduced cardiac output.</td>
<td>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.</td>
</tr>
<tr>
<td>11,12</td>
<td>Survey of body systems</td>
<td>Identify the source, target, and role of progesterone</td>
<td>Knowledge, Comprehension</td>
<td>1,2</td>
<td>The secretion of progesterone stimulates</td>
<td>The target tissue for prolactin is/are the thyroid gland.</td>
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<tr>
<td></td>
<td>Survey of body systems</td>
<td>Describe the function of the organs and structures of the respiratory system.</td>
<td>Knowledge, Comprehension</td>
<td>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.</td>
<td>The lymphatic organ/structure that gradually decreases in size after puberty and also becomes increasingly fibrous is the spleen liver thoracic duct tonsil thymus.</td>
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<td>13,14</td>
<td></td>
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<td>Knowledge, Comprehension</td>
<td>1,2</td>
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<td>15,16</td>
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<td>1,2</td>
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<td>17,18</td>
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<td>Knowledge, Comprehension</td>
<td>1,2</td>
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<td>19,20</td>
<td></td>
<td></td>
<td>Knowledge, Comprehension</td>
<td>1,2</td>
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</tr>
</tbody>
</table>

Major hormones:
- secretory activity in the glands of the breast
- contraction of uterine muscles
- secretory activity of the uterine endometrium
- development of the female secondary sexual characteristics
- loss of the stratum functionalis of the uterine endometrium

Adrenal medulla mammary glands gonads adrenal cortex.
| 21,22 | Regulation of water intake and output/Chemical composition of major fluid compartments/Buffe r systems | Explain the role of organ systems in maintaining chemical, fluid, and acid/base balance. | Knowledge, Comprehension | Water moves in and out of body compartments by what mechanism? | Potassium, magnesium, and phosphate ions are the predominant electrolytes in plasma | Potassium, magnesium, and phosphate ions are the predominant electrolytes in plasma interstitial fluid intracellular fluid blood lymph | 1,2 | 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.
EXTENDED REFERENCE LIST


