<table>
<thead>
<tr>
<th>Book Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revision of an Undergraduate Anatomy lab</td>
</tr>
<tr>
<td>Contralesional Repair of the M1</td>
</tr>
<tr>
<td>NSAIDs and Skeletal Muscle Repair</td>
</tr>
<tr>
<td>A MOOC for Undergraduate Respiratory Physiology</td>
</tr>
<tr>
<td>Using a Minimal Number of Cadavers</td>
</tr>
<tr>
<td>Escape Room Concepts applied to Pathophysiology</td>
</tr>
<tr>
<td>Healthy and Cancerous Pancreatic Tissue Dissection</td>
</tr>
<tr>
<td>Core Concepts for Anatomy and Physiology</td>
</tr>
<tr>
<td>Outcomes for Active Learning</td>
</tr>
<tr>
<td>Learning Management Systems</td>
</tr>
<tr>
<td>Innovative Teaching in Gross Anatomy</td>
</tr>
<tr>
<td>Community Outreach in Anatomy and Physiology</td>
</tr>
<tr>
<td>Pathophysiology Models in a Large Lecture Hall</td>
</tr>
<tr>
<td>Pulling the Plug on Microscopes</td>
</tr>
<tr>
<td>Song Writing to Learn Anatomy and Physiology</td>
</tr>
<tr>
<td>ePortfolios in Anatomy and Physiology</td>
</tr>
<tr>
<td>Student Behavior When Watching Videos</td>
</tr>
<tr>
<td>Importance of Evolutionary Knowledge in Medicine</td>
</tr>
<tr>
<td>Modular Labs in Anatomy and Physiology</td>
</tr>
<tr>
<td>An In-House Anatomy Atlas</td>
</tr>
<tr>
<td>Case Studies in Anatomy and Physiology</td>
</tr>
<tr>
<td>Words, Meaning and Infograms</td>
</tr>
</tbody>
</table>
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# SUMMER 2017 HAPS EDUCATOR TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>By:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FROM THE HAPS PRESIDENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>From the HAPS President</td>
<td>Ron Gerrits</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BOOK REVIEW</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Book Review</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anatomically adrift - mad genius lost in the Victorian world</td>
<td>Jon Jackson, PhD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EDUCATIONAL RESEARCH</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educational Research</td>
<td></td>
</tr>
<tr>
<td></td>
<td>An Undergraduate Anatomy Lab Revision Success Story</td>
<td>Kerrie McDaniel, PhD and Jerry Daday, PhD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CURRENT TOPICS IN ANATOMY AND PHYSIOLOGY</strong></td>
<td>Current Topics</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Current Topics in Anatomy and Physiology</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The Contralesional Repair Mechanism That Leads to the Recovery of Motor Function After Ischemia of the Primary Motor Cortex</td>
<td>Michael P Lembotesis, Brie Paddock PhD, Sarah Cooper MEd</td>
</tr>
<tr>
<td></td>
<td>The Possible Effects of Non-steroidal Anti-inflammatory Drugs (NSAIDs) on the COX-2 Pathway of Skeletal Muscle Repair</td>
<td>Megan Obarowski, Sarah Cooper MEd, John Daley, PhD, and Randy Tammara, PharmD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PERSPECTIVES ON TEACHING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Perspectives on Teaching</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A Massive Open Online Course (MOOC) for Implementing Pedagogical Tools in Undergraduate Respiratory Physiology</td>
<td>Sophie Dandache, PhD, Mariane Frenay, PhD, Marie-Claire Van Nes, MD, MA, MBA, and Franck Verschuren, MD, PhD</td>
</tr>
<tr>
<td></td>
<td>A Method for Maximizing Dissection Experience with a Minimal Number of Cadavers in an Undergraduate Human Gross Anatomy Laboratory Course</td>
<td>Catherine E. Mattinson, PhD and Elisa M. Konieczko, PhD</td>
</tr>
<tr>
<td></td>
<td>Bringing Escape Room Concepts to Pathophysiology Case Studies</td>
<td>S. Richelle Monaghan, PhD and Scott Nicholson, PhD</td>
</tr>
<tr>
<td></td>
<td>Comparison of Healthy and Cancerous Pancreatic Tissue Though Dissection and Imaging</td>
<td>Abraham N. Baker</td>
</tr>
<tr>
<td></td>
<td>Do You Know What It Means? Words, Meaning and Infograms</td>
<td>Vasilii Kolchenko, MD, PhD</td>
</tr>
<tr>
<td></td>
<td>Does Active Learning Achieve Desired Outcomes: Conflicted Pedagogy?</td>
<td>Mari K. Hopper, PhD</td>
</tr>
</tbody>
</table>

*continued on next page*
<table>
<thead>
<tr>
<th>Title</th>
<th>By:</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engaging Students and Simplifying Your Life By Utilizing More Features of Learning Management Systems</td>
<td>Julia Michelle Dais, PhD</td>
<td>92</td>
</tr>
<tr>
<td>Eighty Students, Five Cadavers, and Two Professors: Innovative Teaching Practices in an Undergraduate Human Gross Anatomy Course</td>
<td>Elisa M. Konieczko, PhD and Catherine E. Mattinson, PhD</td>
<td>95</td>
</tr>
<tr>
<td>Establishment of an Interactive Community Outreach program in Human Anatomy and Physiology: The HAPI Lab Model.</td>
<td>Bridgett R Severt MS, Barbara Kraszpulska PhD, and Thomas L Brown PhD</td>
<td>101</td>
</tr>
<tr>
<td>Introducing Pathophysiology Models into a Large Lecture Hall: Investigation of the Effectiveness of Guided Inquiries Involving Movement Outside the Classroom and Independent Learning</td>
<td>Zoë Soon PhD, Melanie Robles, BHK, Stephanie McKeown PhD, and Heather Hurren MEd</td>
<td>106</td>
</tr>
<tr>
<td>Pulling the Plug on Microscopes in the Anatomy and Physiology Laboratory</td>
<td>Zvi Ostrin, PhD and Vyacheslav Dushenkov, PhD</td>
<td>112</td>
</tr>
<tr>
<td>Songwriting To Learn: Can Students Learn Anatomy and Physiology by Writing Content-Rich Lyrics?</td>
<td>Gregory J. Crowther, Allison J. Ma, and Jennifer L. Breckler</td>
<td>119</td>
</tr>
<tr>
<td>Using ePortfolios in Anatomy and Physiology</td>
<td>Lisa J. Hight, EdD and Michelle A. McDonald, MS</td>
<td>124</td>
</tr>
<tr>
<td>Observation of Student Behaviors When Watching Online Tutorial Videos and Strategies to Increase Student Engagement</td>
<td>He Liu, PhD and Mary Vagula, PhD</td>
<td>128</td>
</tr>
<tr>
<td>Student Perceptions of the Importance of Evolutionary Knowledge in Medicine: A Case Study from an Undergraduate Anatomy &amp; Physiology Course</td>
<td>Mark V. Tran, PhD</td>
<td>131</td>
</tr>
<tr>
<td>Utilizing Modular Labs in Human Anatomy and Physiology: Lessons Learned From a First Time Experience</td>
<td>Jennifer R. Zitzner, PhD</td>
<td>137</td>
</tr>
<tr>
<td>Visual? We’ve Got You Covered: An In-House Anatomy Atlas Improves Students Learning</td>
<td>Jennifer Hutchinson BSc, BScN, RN, Rex Thangarajah PCP, AEC, Med Tech, Hilary Hough GD, Hisham S. Elbatarny MB BCh, MSc, MD</td>
<td>144</td>
</tr>
<tr>
<td>What, How, and Why: Writing Interview-based Cases Helps Students Connect Anatomy and Physiology Concepts to Real Life</td>
<td>Tracy L. Ediger, PhD</td>
<td>148</td>
</tr>
</tbody>
</table>
The HAPS-Educator, The Journal of the Human Anatomy and Physiology Society, aims to foster teaching excellence and pedagogical research in anatomy and physiology education. The journal publishes articles under three categories. Educational Research articles discuss pedagogical research projects supported by robust data. Perspectives on Teaching articles discuss a teaching philosophy or modality but do not require supporting data. Current Topics articles provide a state-of-the-art summary of a trending topic area relevant to anatomy and physiology educators. All submitted articles undergo peer-review. Educational Research articles will additionally be reviewed for the quality of the supporting data. All submissions are disseminated to non-HAPS members one year post-publication via the Life Sciences Teaching Resource Community database.

The HAPS Educator is published in April, August and December. The deadlines for submission are March 15, July 15 and November 15.

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Experimental animals must be handled in accordance with the author’s institutional guidelines and informed consent must be obtained for studies on humans. It is the responsibility of the author(s) to secure IRB approval for research on humans.

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Pathway to the HAPS Presidency: If I can do it, so can you!

Ron Gerrits

I suspect none of the previous HAPS presidents had the presidency in mind when they first joined the society. It is a position that you grow into through involvement in the society, making it one of those journeys filled with both effort and reward along the way. Because it may not always be clear how one ends up in such a position, I thought it might be useful to describe my journey, and do a little bit of “name-dropping” along the way. Certainly I won’t list everyone that I have been impacted by, but my intent is to provide a sampling of how I have benefitted, and been impacted by, the members of HAPS that are passionate about anatomy and physiology education.

After earning an undergraduate degree in biomedical engineering at Milwaukee School of Engineering (MSOE), I moved across town to earn my doctorate in physiology at the Medical College of Wisconsin (MCW). During my time at MCW, MSOE started a nursing program and was looking for faculty to cover a few life-science courses for these students. My doctoral advisor was kind enough to allow me to teach a couple of these courses and it was that experience that convinced me that a career in teaching was likely the best fit for me. Upon completion of my Ph.D. it was back to MSOE to coordinate a series of life-science courses that had been managed by part-time faculty up to that point.

Those first few years were a tremendous amount of work – much more than I had expected, even with the experiences I had obtained while in graduate school. Teaching a full course load, including some topics I was not completely comfortable with (i.e. microbiology) lead to a lot of regular searches for materials that could aid my efforts. These were the days when there was much less information available (at least easily available) than there is today. A colleague recommended that I investigate HAPS to see if it would provide some benefit, so it was off to my first HAPS meeting in Phoenix in 2002.

I had previously attended some very large meetings (Experimental Biology, Neuroscience) and I immediately felt a difference when attending my first HAPS meeting. It felt less “competitive” than the large scientific meetings and more “cordial”. Phil Tate constantly reminded us about how “hot” it was, but he also pointed out that it was a “dry heat”, as he filled in between speakers with his related jokes. As a first timer, some friendly HAPSters invited me to lunch on the first day because I was attending the meeting without initially knowing anyone else there. Over another lunch I met Rod Seeley, and at dinner, Dee Silverthorn. These were names I was aware of because they were authors, but meeting them gave a whole new perspective to the fact that they were regular people, just more knowledgeable and skilled at writing than I was. A few of the others I recall meeting in 2002 were Tom Lehman, John Waters, Judi Nath and Terry Harrison. Tom and John went on to serve as president of the society, Judi is currently president-elect and Terry hosted the Denver conference. The workshops at that first meeting aided me in lab development and helped with some analogies used in class. I attended the Curriculum and Instruction (C&I) committee meeting where they were talking about the benefit of putting together a list of learning outcomes, something I wished they had already. I signed up for the listserv to be able to extend my conversations beyond the conference. After obtaining a ride to the airport from another friendly HAPSter (Gary Johnson), I was hooked.

Since that time I have not attended every HAPS annual conference, but I have made most. For several years I was a member of the C&I committee, teaming up with Tom Lancraft to draft the learning outcomes for the endocrine, fluid and electrolytes and portions of some of the other sections. Eventually I took over as chair of this committee and worked to make some adjustments to the learning outcomes. We put together a list of free electronic resources (now long-outdated) and designed oversight of some of the task forces, etc. Sure it was work, but work that I, and many others, could benefit from directly. After completing two terms as chair of C&I, I was asked to chair the steering committee, which is comprised of the various committee chairs. Together we shared the same goal of developing resources that would benefit the membership. The progress on these projects has often been slow, but they are also steady. I would encourage all of you to become involved in some way on a HAPS project.

Along the way my participation in HAPS lead to a variety of other beneficial relationships. Meeting Murray Jensen on a bus in Philadelphia ultimately led to my involvement in his NSF funded project to develop Process Oriented Guided Inquiry Learning activities for physiology. When I chaired the C&I committee I was contacted by the project manager of the Open Learning Initiative Project’s Introductory Anatomy and Physiology course, which I, and several other HAPS members (Terry Thompson, Hiranya Roychowdhury, Wendy Riggs, Anna Davis, others) ultimately worked on. This position lead to a similar project working on a high school course for the National Academy Foundation. Attending a workshop on development of the Phys-MAPS project allowed me to act as a reviewer and site tester for their assessment materials ..... and the list goes on. Projects and positions stemming from HAPS involvement now build most of my CV and were primarily responsible for the advancement in ranks at my institution.

Although involvement with various projects has benefitted both myself and others, it is the relationships that I really look forward to. Interacting with those who are like-minded, who are focused on education and willing to help, is the best part of HAPS. When I was nominated for the position of president, it was a nomination I had to think long and hard about. Not because I did not want to take it on, but because I questioned whether I have the time and energy to keep a great thing going. In the end I accepted because HAPS has given me a lot, and it requires people like me to give back. I suspect there is a similar roadmap for those who have served before me – and a path that you may be on (or be willing to start) yourself!
Anatomically adrift – mad genius lost in the Victorian world

Jon Jackson, PhD — Columbus, OH

Books reviewed in this essay:


The Resurrectionist, New Jersey artist E. B. Hudspeth’s first book, purports to be two books in one: the first is a short biography of Dr. Spenser Black, a celebrated, but controversial surgeon of the late 19th century; the second is an extravagantly illustrated “Gray’s Atlas”-style accounting of beasts from Greco-Roman mythology, called Codex Extinct Animalia. How does one say it: what’s good isn’t new, and what’s new isn’t all that good.

All in all, The Resurrectionist is something best left to sit on a shelf (or your shopping cart) undisturbed. While reading, my sense of déjà vu was screaming. It seems clear to me that The Resurrectionist is based loosely on Alisdair Gray’s 1992 novel Poor Things. Lengthily subtitled Episodes from the Early Life of Archibald McCandless, MD, Scottish Public Health Officer, Gray’s novel was something fresh, supposedly edited by Mr. Gray, but written by Dr. McCandless, with an afterword by a woman who may or may not have been his wife. Reviewers at the time praised Poor Things for its darkly comic send-up of both McCandless and the medical establishment of the late Victorian era. However, it was Archibald’s classmate Godwyn Baxter—whose nickname “God” presaged some of the book’s historicity— who was really the lead player in this tale. In the hulking, monstrous surgical genius of Baxter, one readily sensed a Scottish palimpsest of Mary Shelley’s Frankenstein. When Baxter brought back to life a pregnant woman who drowned herself to escape an abusive husband, he could only give her a brain from her unborn daughter. What could go possibly wrong with this? Imagine if Young Frankenstein was directed by a droll Scotsman rather than Mel Brooks and you’ll have an idea. Unlike The Resurrectionist, the pan-European adventure told in Poor Things was so well-written, it captured the attention of readers and critics alike; garnering both the 1992 Whitbread Award and the Guardian Prize for fiction.

However much it owes a debt of gratitude to Poor Things, The Resurrectionist fails to both be dark enough, and believable enough (as “found” biographies go — this is very lame) to move all but the most labile of readers. Spencer Black isn’t really believable as a man, much less as a doctor. The sheer brevity of the written biography fails to allow Hudspeth sufficient time and process to endow his main characters with anything resembling gravitas or meaning. The second part of the book, the so-called Codex Extinct Animalia, is hailed as the mad genius Dr. Black’s magnum opus, is riddled with sloppiness at times so cloying as to choke off even a good-natured attempt to suspend disbelief and play along. The Gray’s Anatomy aspect of the Codex, for instance, might well be of interest to those who would like to share the book as a parlor gift, but Hudspeth apparently was so hasty to get the book out that he didn’t even double check his own figures for consistent labelling. [It’s one thing for a four-armed creature to have two sets of scapulae, it’s quite another for the bone labeled femur on one side to be labeled fibula on the other side]. While the detail of the drawings is very precise and wonderful, it breaks down quickly thereafter. Note to self: when designing animals and illustrating them, consult with some sort of anatomical expertise.

Still, given the recent popularity of Steam Punk and other Fantastic Creatures of the J.K. Rowling kind, one might see how this meager line of a story could, in the right hands, become the basis for a truly terrifying movie. No big surprise then, when time came to look up the prosaic publication details of this very book on the smile.amazon.com website, the book site was also featuring a video with a voice-over reading bits of the “last letter” of Dr. Spencer Black to his brother Bernard. In two minutes, the video suggestively conveyed and engaged me in ways that reading and poring over the book itself could not, suggesting that this whole project was designed to pitch a screenplay idea. Perhaps the movie idea has yet to find a producer capable of something more than the promo clip. We (and it) can only wait and hope for redemption through the silver screen. For now, The Resurrectionist, like some of the subjects it describes, is something that is best left buried.

Jon Jackson, PhD  is the Western Regional Director of HAPS, and is currently Visiting Professor of Anatomy at The Ohio State University College of Medicine, where he teaches Gross Anatomy to Dental, Graduate, and Medical students. He is also a Fellow in the History and Philosophy of Science at the Institute for Philosophy in Public Life at the University of North Dakota.

About the author
Jon Jackson, PhD  is the Western Regional Director of HAPS, and a member of the Pre-Requisite Survey Task Force. He is currently Visiting Professor of Anatomy at The Ohio State University College of Medicine, where he teaches Gross Anatomy to Dental, Graduate, and Medical students. He is also a Fellow in the History and Philosophy of Science at the Institute for Philosophy in Public Life at the University of North Dakota.

Back to TOC
An Undergraduate Anatomy Lab Revision Success Story

Kerrie McDaniel, PhD1 and Jerry Daday, PhD2
1Department of Biology, Western Kentucky University, 1906 College Heights Blvd.
Bowling Green, KY 42101
2Department of Sociology, Executive Director, Center for Innovative Teaching and Learning, Western Kentucky University, 1906 College Heights Blvd., Bowling Green, KY 42101
Kerrie.mcdaniel@wku.edu, Jerry.daday@wku.edu

Abstract
The Anatomy and Physiology lab at Western Kentucky University was revised to increase formative assessment through the use of e-texts and e-material, introduce hands-on learning via the Anatomy in Clay® System, and provide context for content in the form of case studies and course sequencing. Success of the revision was measured through analysis of grade distributions before and after the revision, coupled with self-administered surveys to measure student perceptions of the course. The percentage of students earning Bs and Cs in the revised lab course increased, while the percentage of students earning Ds and Fs declined. A majority of students expressed positive perceptions of the changes in pedagogy that occurred in the lab revision. A higher percentage of students repeating the course responded “agree” or “strongly agree” to statements regarding changes to the lab than students taking the course for the first time. doi: 10.21692/haps.2017.010

Key Words: assessment, MCQ, two-tier question, teaching, justification

Introduction
The need for healthcare workers is increasing (Factsheet 2014, Fox and Abrahamson 2006). Healthcare fields such as nursing, physical therapy and pharmacy face future shortages of qualified personnel to fill important positions. Universities are charged with producing highly-qualified professionals to fill these needs. University-level anatomy and physiology laboratory courses are an important part of the undergraduate curriculum in these areas and often serve as gatekeepers into these professional programs. Student success in anatomy and physiology is often dependent on the dedication of the student and the student’s ability to memorize rather than to understand the material (Miller et al. 2002). Low budgets and lack of time can steer pedagogy towards traditional methods of memorizing figures and diagrams or observing plastic models in groups rather than towards interactive exercises that provide context for learning (Jones et al. 2014). Lack of student engagement and lack of prerequisite courses lead to a high number of students who fail anatomy and physiology (Hull et al. 2016; Lunsford and Herzog 1997). Developing ways to reduce attrition rates and increase student success is a goal of anatomy and physiology educators. Driven by a need to increase student success, the human anatomy and physiology lab at Western Kentucky University was revised from a traditional pedagogical model to a new system that maximized several methods of student engagement and the use of formative assessment. Our hypothesis was that students who were enrolled in the newly revised lab after having received a failing grade in the traditional lab in a prior semester would have a more favorable view of the new pedagogies implemented compared to students enrolled in the newly revised lab for the first time.

The Traditional Model
The traditional model was void of technology, had no defined goals or objectives, and lacked formative assessment, relying instead on four, high-stakes practical exams. Lab exercises for the skeletal and muscular systems involved students memorizing bones and muscles using charts, figures, plastic models and disarticulated skeletons. Histology labs witnessed frustrated students trying to focus microscopes on tissues that had no known relevance to the students and their learning. The immense amount of material covered, tedious pedagogy and the absence of required prerequisites was a recipe for failure (Hull et. al 2016).

The New Model/Revision
The revised human anatomy and physiology lab was designed to:
1) increase the use of formative assessment
2) accommodate affordable, hands-on learning
3) provide context for learning
The topic outline and rigor of the lab did not change from the previous, traditional model, but clear goals and objectives were established based on the content, rigor and discussions with the relevant stakeholders, such as the Nursing Department and Physical Therapy Program (Figure 1). Students were still required to learn the names of the
muscles, origins, insertions and actions in the newly revised lab, but student expectations were clearly stated and the methodology was altered to increase the use of formative assessment, context and active, hands-on learning.

E-texts and e-materials were adopted from McGraw Hill as one mechanism to increase the practice of providing students with formative assessment. E-materials refer to the digital materials that are available to instructors and students that complement the required e-text. These materials include online digital homework assignments, simulations, animations, videos, and virtual dissection programs. Using e-materials to provide formative assessment has been shown to be potentially less threatening to students than direct interaction with the instructor and can be optimized by the instructor to ensure that assignments and feedback meet the goals and objectives of the course (Blok et al. 2002). Timmerman and Kruepke (2006) reported that the ability of e-materials to provide readings, animations and/or videos to remediate missed questions makes it an effective way to provide formative assessment. Students were required to complete assigned reading and accompanying digital homework assignments before attending lab to ensure that they attended lab sessions more prepared. Compulsory pre-class assignments have been shown to improve student learning outcomes in biology courses (Moravec et al. 2010). In the revised lab, immediate feedback was provided on the assignments so that students could see exactly what they did not understand and were directed to information in the text to help them master the content. The e-text assignments allowed for “skill and drill” practice on basic anatomy and offered metacognitive data and feedback on areas where a student needed more practice. Formative assessment through the e-text and e-materials offered immediate feedback. These assignments also have been shown to help students learn additional mechanisms to prepare for summative exams (Linn and Eylon 2011).

Active learning practices are known to support student learning (Michael 2006, Daniel 2016). Hands-on learning in the anatomy and physiology lab without the use of cadavers poses challenges. Traditionally, these laboratories were taught using expensive dissections of non-human specimens, or by requiring students to memorize and regurgitate anatomical structures using diagrams, figures and models (Jones et al. 2014). While cadaver dissection is classically the most accepted way to teach anatomy, it has become rare in the undergraduate classroom due to increased class sizes and dwindling financial resources (McLachlan et al. 2004, McLachlan and Patten 2006, Reidenberg and Laitman 2002, Sugand et al. 2010). Students who are not motivated to sit with a figure or diagram and memorize it struggle in these courses.

Our search for an affordable, hands-on method to teach anatomy was driven by the desire to introduce higher order thinking and application skills into a lab that was largely focused on knowledge acquisition and toward the bottom of the pyramid in Bloom’s taxonomy (Bloom et al. 1984). During the development of the revised lab, the P-12 Next Generation Science Standards cross-cutting concepts of “Structure and Function” and “Modeling” seemed to be a good place to start (National Research Council 2014). As an alternative to the practice of dissection and memorization of figures, we chose to adopt the Anatomy in Clay® System. This system directs students to build anatomical structures, such as muscles, blood vessels, nerves and organs (heart, brain, kidneys, lungs, bladder etc.) in clay and place them on 15 inch skeletal models called Manikens®. Students must understand the anatomy well enough to create a scale model of the muscle or organ and place it in the proper location on the Maniken®.

Creation, analysis and application are higher-order thinking skills in Bloom’s taxonomy (Bloom et al. 1984). The pedagogical sequence used in most lab exercises began by capturing the interest of students through an interesting image, case study, or analogy followed by a brief review of the anatomy studied in the pre-lab homework assignments and readings. This might involve using Power Point images or figures from the text. The bulk of the lab time was spent making clay models of the anatomy on the Maniken®. The model was subsequently compared to actual anatomy either via a virtual dissection, a microscopic observation of actual histological specimen, or by examining actual bones and skeletons (Figure 2). Understanding and discussing the
constraints of a model and comparing the model to the “real thing” is an important part of using these models as teaching tools (National Research Council 2014).

The clay system was used to learn muscles, the heart and blood vessels, the reflex arc, the urinary system, and the lungs. Advanced labs used the clay system to build lymphatics, the female breast, the brain, and nerves. The layering of anatomy onto other structures was a strength of this system. After the pre-nursing majors had built the median cubital vein and the basilic and cephalic veins superficial to the muscle of the arm, students reported that they were less worried about striking an artery when drawing blood. Clay was also used to build models of tissue types. The three-dimensional difference between simple squamous epithelium and simple cuboidal epithelium is very evident when models were molded in clay. We hypothesized that these strategies would promote active learning in the labs, and enhance and deepen student learning and overall success in the course.

Learning content in context promotes deeper and lasting understanding of the assigned material and forces students to learn using higher order thinking levels (Ahmed et al. 2010, De Bere and Mattcik 2010). Context was added to the labs in several unique ways. The first was the timing and testing of complementary anatomical content. In the traditional model, students were asked to memorize all the bones and bone markings of the human body from diagrams and were given one large practical exam. A couple of weeks later students memorized figures of muscles and a chart of origins, insertions and actions followed by one large exam. In both of these examples, students were not provided with context for their learning nor mechanisms of formative assessment and practice. Student grades were typically poor.

The revised model still required students to learn all the bones and bone markings and all the muscles along with the origins, insertions and actions. However, the bones were divided into three groups: bones of the axial skeleton, bones of the upper body and bones of the lower body. Students were assigned one group of bones per week and a practical quiz over the bones and bone markings was administered at the beginning of the lab period. After the quiz, the muscles of the region where the bone markings were located were introduced. For example, the muscles of the head and neck where built in clay on the bones and bone markings of the skull and vertebrae of the 15 inch Manikens®. Often the bone markings over which they were just tested served as origins or insertions for the muscles. In this way, students saw the value of bone marking as points of attachment for muscles and made stronger connections to the material (Figure 3). Context was also added into the lab via case studies. When students learned about the reflex arc of the nervous system as it related to Christopher Reeves’ cervical spine injury, it suddenly became extremely interesting. Real life connections

Figure 3. Example of content sequencing of bones/bone markings and muscles in lab revision.
and context give students a reason to learn more about a topic (Bockers et al. 2013).

Methods
Human anatomy and physiology at Western Kentucky University is a 100-level course with no required prerequisites. This course is a requirement for admission into the nursing program, dental hygiene program, pre-pharmacy, pre-physician assistant, pre-physical therapy and exercise science. Approximately 400 students enroll in 16-22 individual sections of this one-semester, lecture/lab course.

Two data sources were used to assess the efficacy of the lab revision. The first data source included grade data collected pre- and post-implementation of the lab revision. Lab grade data were collected for spring semesters (from 2008 to 2012) prior to implementation of the revision and spring and fall semesters after the revision (2013-2016). Numerical grades were gathered pre- and post-implementation and the numerical grades were grouped into the following categories:

- 90-100% lab score = A
- 70-89% lab score = B/C
- 69% and below lab score = D/F

A cross-tabular analysis with a Chi Square test of statistical significance was used to compare the lab grades pre- (N=653) and post-revision (N=1594) to determine if altered pedagogy impacted grades (Table 2). Since topics and content were constant, changes in grades were likely due to alterations in pedagogy.

The second data source included the use of an anonymous, online survey. Students enrolled in the anatomy and physiology lab were invited to participate in an anonymous online survey measuring their perceptions about the revised laboratory near the end of the semester. Students were offered a small amount of extra credit as incentive to complete the survey. A total of 874 students were enrolled in the revised anatomy and physiology lab when surveys were administered at the time of this study. Among this total population of students enrolled in this lab, 720 respondents completed the online survey, yielding a participation rate of 82.4%. The majority of the sample was comprised of students who were women (78%), white (81.6%), and of traditional age (100%), which is defined as students who are less than 26 years old. The majority of the students were in their first or second year of college (74.5%). Approximately half of the students had a cumulative GPA of at least 3.00 when they completed the survey instrument.

Student perception and satisfaction are viewed as learning outcomes or products of a student’s mental evaluation of his/her achievement level (Keller and Bless 2008). Student perceptions appraise how useful methods are to the learner in the context of the grade earned. The use of student perception surveys for anatomy education is not novel in the medical school community (Cho and Hwang 2013, Fitzpatrick et al. 2001). We hypothesized that students would have a positive perception of the modified lab pedagogy because of the focus on regular formative assessment, active learning opportunities, and an understanding of how the content is used in the “real world”.

In addition to questions about demographics, the survey instrument had 40 closed-ended questions that measured three constructs of the lab revision including:

1) the increased use of formative assessment in the form of e-text and e-materials
2) the addition of hands-on learning
3) the provision of context for content

A standard Likert scale was used to measure student perceptions for each indicator (Strongly Disagree = 1; Disagree = 2; Neither Agree nor Disagree = 3; Agree = 4; Strongly Agree = 5). Survey questions within each of the five major areas were summed into an additive index. To preserve a range of 1 to 5, the total summed score was divided by the total number of indicators for each index. A Cronbach’s alpha test was employed to assess the reliability of the combined items before each scale was constructed. The specific indicators used on the survey instrument to create these additive indices are presented in Table 3 along with the corresponding Cronbach’s alpha score. All three of the additive indices (the formative assessment via E-Materials Index, the Context and Sequence Index, and the Use of Hands-on Materials Index) had values of .700 or higher, which is a standard threshold used prior to creating

Table 1: Distribution of First-time Students and Repeating Students in Current Study

<table>
<thead>
<tr>
<th>Enrollment Status</th>
<th>%</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-time Taking Course</td>
<td>83.5</td>
<td>601</td>
</tr>
<tr>
<td>Repeating Course</td>
<td>16.5</td>
<td>119</td>
</tr>
</tbody>
</table>

Table 2: Chi Square Analysis of Anatomy Lab Grades Pre and Post Intervention

<table>
<thead>
<tr>
<th>Grades</th>
<th>Pre-Intervention (Revision) % (N)</th>
<th>Post-Intervention (Revision) % (N)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>D &amp; F</td>
<td>49.3 (322)</td>
<td>42.0 (669)</td>
<td>.002</td>
</tr>
<tr>
<td>B &amp; C</td>
<td>38.4 (251)</td>
<td>46.2 (737)</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>12.3 (80)</td>
<td>11.8 (188)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100 (653)</td>
<td>100 (1,594)</td>
<td></td>
</tr>
</tbody>
</table>

Chi-Square: 12.147

Table 3: Perceptions of Pedagogical Methods Used in Revised Lab by All Student Enrolled

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Strongly Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I felt confident about using the bone e-materials for learning</td>
<td>5.01 (322)</td>
<td>25.84 (1,594)</td>
<td>25.49 (1,594)</td>
<td>25.49 (1,594)</td>
</tr>
<tr>
<td>I felt confident about using the bone e-materials for learning</td>
<td>5.42 (322)</td>
<td>25.84 (1,594)</td>
<td>25.49 (1,594)</td>
<td>25.49 (1,594)</td>
</tr>
</tbody>
</table>

continued on next page
<table>
<thead>
<tr>
<th>Pedagogical Change</th>
<th>Strongly Disagree (%)</th>
<th>Disagree (%)</th>
<th>Neither Agree or Disagree (%)</th>
<th>Agree (%)</th>
<th>Strongly Agree (%)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Use of E-texts and materials for form assessment</strong> (Alpha=.70)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I liked using e-text compared to paper text.</td>
<td>25.49</td>
<td>29.39</td>
<td>15.18</td>
<td>20.06</td>
<td>9.98</td>
<td>718</td>
</tr>
<tr>
<td>The e-homework assignments helped me to learn the material.</td>
<td>6.28</td>
<td>8.61</td>
<td>10.88</td>
<td>52.72</td>
<td>21.62</td>
<td>717</td>
</tr>
<tr>
<td>I liked having e-homework assignment that I had additional points to help my grade.</td>
<td>2.65</td>
<td>1.96</td>
<td>3.91</td>
<td>21.98</td>
<td>59.5</td>
<td>716</td>
</tr>
<tr>
<td>I would rather take a course that used the e-learning material than one that does not.</td>
<td>10.28</td>
<td>22.22</td>
<td>33.19</td>
<td>24.86</td>
<td>9.44</td>
<td>720</td>
</tr>
<tr>
<td>I preferred to print off the e-documents use them rather than use them electronically.</td>
<td>25.84</td>
<td>30.2</td>
<td>24.16</td>
<td>15.73</td>
<td>4.07</td>
<td>712</td>
</tr>
<tr>
<td><strong>Context and Sequencing</strong> (Alpha=.75)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The e-homework assignments helped me learn the bone markings.</td>
<td>5.42</td>
<td>6.95</td>
<td>14.74</td>
<td>53.41</td>
<td>19.47</td>
<td>719</td>
</tr>
<tr>
<td>I felt confident about using the bone markings I learned in the homework to build muscles in lab.</td>
<td>5.01</td>
<td>16.43</td>
<td>31.2</td>
<td>38.72</td>
<td>8.64</td>
<td>718</td>
</tr>
<tr>
<td>Using the previously learned bone markings to build muscles in lab helped me remember them by use in a practical application.</td>
<td>3.61</td>
<td>13.47</td>
<td>27.36</td>
<td>45.56</td>
<td>10</td>
<td>720</td>
</tr>
<tr>
<td>I liked using case studies in lab.</td>
<td>2.51</td>
<td>8.91</td>
<td>32.31</td>
<td>45.82</td>
<td>10.45</td>
<td>718</td>
</tr>
<tr>
<td>The case studies helped me learn the material by seeing practical applications.</td>
<td>2.38</td>
<td>7.01</td>
<td>29.17</td>
<td>49.79</td>
<td>11.64</td>
<td>713</td>
</tr>
<tr>
<td><strong>Hands-On Learning</strong> (Alpha=.89)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using the Manikens™ helped me learn names of the bones.</td>
<td>9.04</td>
<td>20.86</td>
<td>19.61</td>
<td>37.13</td>
<td>13.35</td>
<td>719</td>
</tr>
<tr>
<td>I liked using the Anatomy in Clay System.</td>
<td>12.71</td>
<td>16.06</td>
<td>21.79</td>
<td>35.34</td>
<td>14.11</td>
<td>716</td>
</tr>
<tr>
<td>Using the Manikens™ helped me learn the anatomical terms and surface anatomy.</td>
<td>5.7</td>
<td>12.93</td>
<td>22.91</td>
<td>46.04</td>
<td>12.52</td>
<td>719</td>
</tr>
<tr>
<td>I liked building muscles in clay.</td>
<td>16.46</td>
<td>22.59</td>
<td>22.59</td>
<td>28.59</td>
<td>9.76</td>
<td>717</td>
</tr>
<tr>
<td>Building muscles in clay helped me remember the names of the muscles and their origins, insertions and actions.</td>
<td>14.86</td>
<td>25.28</td>
<td>22.92</td>
<td>29.72</td>
<td>7.22</td>
<td>720</td>
</tr>
</tbody>
</table>

*Table 3: Perceptions of Pedagogical Methods Used in Revised Lab by All Student Enrolled*
<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Min. Value</th>
<th>Max Value</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeating Course (1=no; 2=yes)</td>
<td>1.16</td>
<td>0.37</td>
<td>1.0</td>
<td>2.0</td>
<td>720</td>
</tr>
</tbody>
</table>

### Dependent Variables

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Min. Value</th>
<th>Max Value</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-text and E-material Use Index</td>
<td>2.96</td>
<td>0.68</td>
<td>1.4</td>
<td>4.6</td>
<td>710</td>
</tr>
<tr>
<td>Context and Sequencing Index</td>
<td>3.54</td>
<td>0.62</td>
<td>1.0</td>
<td>5.0</td>
<td>708</td>
</tr>
<tr>
<td>Hands-on Learning Index</td>
<td>3.15</td>
<td>0.99</td>
<td>1.0</td>
<td>5.0</td>
<td>714</td>
</tr>
</tbody>
</table>

**Table 4: Descriptive Statistics of Perceptions of Revised Pedagogy**

<table>
<thead>
<tr>
<th>Perception</th>
<th>Strongly Disagree (%)</th>
<th>Disagree (%)</th>
<th>Neither Agree or Disagree (%)</th>
<th>Agree (%)</th>
<th>Strongly Agree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I learned more in the new format.</td>
<td>5.08</td>
<td>4.24</td>
<td>12.71</td>
<td>32.02</td>
<td>45.6</td>
</tr>
<tr>
<td>I retained more information in the new format.</td>
<td>3.39</td>
<td>3.39</td>
<td>13.56</td>
<td>38.14</td>
<td>41.53</td>
</tr>
<tr>
<td>The new lab is easier to learn (compared to the former lab)</td>
<td>5.08</td>
<td>5.08</td>
<td>14.41</td>
<td>36.44</td>
<td>38.98</td>
</tr>
<tr>
<td>I liked the revised lab more than the previous lab.</td>
<td>2.8</td>
<td>8.6</td>
<td>5.7</td>
<td>45.7</td>
<td>37.1</td>
</tr>
</tbody>
</table>

**Table 5: Perceptions of New Course Structure Among Student Repeating the Course (N=118)**

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Mean</th>
<th>s.e.</th>
<th>95% C.I.</th>
<th>N</th>
<th>t</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E-text and E-material Index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repeating Course</td>
<td>3.18</td>
<td>0.62</td>
<td>3.05-3.30</td>
<td>111</td>
<td>-3.81***</td>
<td>155.8</td>
</tr>
<tr>
<td>First-time Taking course</td>
<td>2.92</td>
<td>0.03</td>
<td>2.37-2.86</td>
<td>597</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Context & Sequencing**                   |       |       |            |    |      |     |
| Repeating Course                          | 3.71  | 0.05  | 3.60-3.81  | 117| -3.45***| 176.0|
| First-time Taking Course                  | 3.51  | 0.03  | 3.46-3.56  | 588|       |      |

| **Hands-on Learning**                      |       |       |            |    |      |     |
| Repeating Course                          | 3.23  | 0.09  | 3.10-3.46  | 118| -1.66* | 171.4|
| First-time Taking Course                  | 3.12  | 0.04  | 3.04-3.20  | 593|       |      |

**Table 6: Comparison of Means for Students Repeating anatomy and physiology lab and Students Taking anatomy and physiology lab for the First Time (Two-Sample T-Test with Unequal Variances Assumed)**

* *=p<.05  ** *=p<.01  *** *=p<.001
an additive index (Peterson 1994). The descriptive statistics for the three indices are presented in Table 4. Perceptions of the three changes made to the anatomy and physiology lab were examined by comparing students enrolled for the first time with repeating students using a two-sample t-test with unequal variances (Table 6). Grade data were also collected for these repeating students to see if perceptions about the pedagogy in the revised lab were consistent with gains or losses in scores (Table 7).

Our sample of 720 students included 119 students (16.5%) who were retaking anatomy and physiology in the revised lab after having failed the course in the traditional format in a previous semester (Table 1). This yielded the opportunity to evaluate student perception of the new lab format by comparing those students who completed the lab under the old format (N=119) with students who were completing the lab in the revised format for the first time. Students who were repeating anatomy and physiology lab under the new method were in the unique position to directly compare the traditional lab with the revised pedagogy. For our empirical analyses we compared student perceptions of the new lab between these two groups. Students who self-identified as being unsuccessful in the traditional format and who were now repeating in its revised format were presented with several additional questions measuring their perception of the changed methods (Table 5).

The Institutional Review Board at Western Kentucky University approved the study based on the ethical guidelines of social scientific research and informed consent was obtained from all participants.

The second data source included student perceptions of the anatomy and physiology lab.

### Results

Cross-tabular analysis with a Chi-square test of lab grades pre-and post-implementation indicated a statistically significant change in the distribution of lab grades before and after the revision (Chi-square=12.147; p<.01) (Table 2). Specifically, the cross-tabular analysis showed a decline in the percentage of students earning Ds and Fs post-implementation (42%) as compared to Ds and Fs earned before the lab revision (49.3%) (Figure 4). As the percentage of Ds/Fs declined after the lab revision, the percentage of students earning B or C grades increased from 38.4% pre-implementation to 46.2% post-implementation (Figure 4). There was virtually no change in the percentage of students earning an A before or after the lab revision, suggesting that these students would likely do well regardless of the different pedagogies used. The positive grade trend shows that a larger percentage of students were successful in the revised A&P laboratory.

<table>
<thead>
<tr>
<th>Percentage of repeating student earning D or F grade pre-revision</th>
<th>Percentage of students earning grade post-revision</th>
<th>Degree of grade change</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Ds and Fs</td>
<td>53% of students improved grade</td>
<td>29% improved one letter grade</td>
</tr>
<tr>
<td></td>
<td>36% of students grades were unchanged</td>
<td>16% improved two letter grades</td>
</tr>
<tr>
<td></td>
<td>11% of students` grades were worse</td>
<td>6% improved three letter grades</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2% improved by four letter grades</td>
</tr>
</tbody>
</table>

Table 7: Comparison of anatomy lab grades for repeating students before and revision.

---

Figure 4: Grades trends pre and post laboratory revision. Revision marked by Vertical black line.
The overall perceptions about the pedagogy used in the revised laboratory suggest that students had a neutral to slightly favorable view of the changes made to the lab (Table 4). Students seemed to appreciate the e-homework assignments as a mechanism to help them learn material, including bone markings, with approximately 73-74% of respondents “agreeing” or “strongly agreeing” with these statements (Table 3).

When the subpopulation of students repeating the course were compared with those students taking the lab for the first time, the two-sample T-test with unequal variance indicated that students repeating the lab had a significantly more favorable view of the new pedagogy compared to students who took the course for the first time (Table 6). First-time students generally have a more negative view of the use of E-materials (2.92) compared to those repeating the course (3.18). The results from the two-sample t-tests show that this difference is statistically significant (p < .001). Repeating students reported significant positive perceptions of the use of hands-on-materials in lab (X1 = 3.28) compared to students taking the lab for the first time (X2 = 3.12 respectively). Additionally, repeating students perceive the Context and Sequencing changes in the course (X1 = 3.71) significantly more favorably (p < .001) compared to the first time students (X2 = 3.51).

In addition to comparing repeating and first-time students using two-sample t-tests, multivariate Ordinary Least Squares (OLS) regression models were employed to determine if the differences between these two groups remained after controlling for demographic variables like gender, race, credit hours and GPA (tables not shown). These analyses revealed that repeating students (code = 1) perceived the use of E-materials for formative assessment (b = .27; p < .000) and the use of context and sequencing (b = .20; p < .01) significantly more positively than first time anatomy and physiology lab students (code = 0) after controlling for gender, race, credit hours completed and GPA. Only one of the indices, the use of hands-on-materials, did not significantly differ between repeat and first-time students net of the control variables (b = .19; p = 0.069). These multivariate OLS models yielded findings that are largely consistent with the results of the two-sample t-tests showing that students who are repeating the anatomy and physiology lab with its new structure have a more favorable view of these new pedagogical changes compared to first-time students.

Fifty-three percent of repeating students improved their letter grade for the anatomy course when taking it for the second time with the revised methodology (Table 7). Thirty-six percent of the repeating students’ grades were unchanged pre- and post-revision. This is interesting within the context that 83% of repeating student responded with an “agree” or “strongly agree” to questions stating that these students “liked” the revised lab methods better than the traditional format (Table 5).

**Discussion**
The revision of the anatomy and physiology laboratory involved the introduction of e-texts and e-materials to provide formative assessment opportunities for students, provision of context (including sequencing material so that it made sense to the student), and sustainable hands-on activities in the lab. The content covered in the lab remained constant before and after the revision so that only the pedagogy changed. Assessments covered the same learning objectives pre- and post-revision and were at the same level of rigor. The change in sequencing of the material did necessitate that practical exams over the bones and bone markings be divided into three shorter assessments covering the span of three weeks rather than one large exam over all of the content (pre-revision). The data on the efficacy of these revisions demonstrated that students perceived some of these changes positively and that grades were impacted by the new pedagogy. While these finding supported our hypotheses, there were aspects that were surprising.

We initially hypothesized that the change in pedagogy would result in a positive shift in the student grade distribution pre- vs. post-implementation. Our results did not completely support this hypothesis, however some important, more nuanced patterns emerged:

1) the percentage of As remained the same pre-and post-implementation
2) the percentage of Ds and Fs decreased significantly
3) the percentage of Bs and Cs increased

Butler and Winne (1995) offer a conceptual model of self-regulation and feedback in which a student draws on his/her prior knowledge and internal feedback to construct his/her own meaning of requirements and formulates personal goals. Self-regulation refers to the ability of a student to monitor his/ her own thinking, motivation and behavior during learning (Pintrich and Zusho 2002). Students who are more effectively able to self-regulate are more capable of achieving their desired goals (Butler and Winne 1995).

A study of first-year medical students, who achieved their undergraduate goal of acceptance into a medical school and are considered to be successful learners, showed that these students were autonomously motivated (Sobral 2004). This type of motivation points to a higher quality of learning and increased effort by these students (Deci et al. 1991). Misch (2002) found that medical students were motivated by both internal and external factors. The lack of variation in the percentage of students who earned As before and after the lab revision is likely due these types of factors. Excellent students likely follow the learning patterns of a self-regulated, intrinsically and extrinsically motivated learner.
There is no need for activities, exercises or context for these students as they can formulate their own internal meaning and requirement for learning (Pintrich and Zusho 2002). In fact, some students found the activities associated with the e-learning environment to be extraneous and represented “busy work”. On the other hand, students who have not learned to successfully self-regulate depend upon external feedback and experiences to formulate context and meaning (Nicol and Macfarlane-Dick 2006). The new lab design offers these students mechanisms such as formative assessment, context and hands-on learning so that they can be successful. The ascending pattern of B and C grades and the descending percentage of Ds and Fs after the lab revision supports this view (Table 2, Figure 4).

While students had a neutral to slightly positive perception of the revised lab course, there were statically significant differences between first-time enrolled students and those students who were in the best position to do a meaningful, direct comparison of the change in pedagogies; that is those students who had participated in both the traditional lab and the revised lab formats. These students would have lacked the formative assessment and skill and drill opportunities in the traditional lab and hands-on activities or context during their first time enrolled in the anatomy and physiology lab course. These unsuccessful students, in their first attempt, fell into the Ds and Fs category of grade distribution in the traditional format. While 53% of students raised their letter grade after the revision by one letter grade or more, thirty-six percent of the grades did not change. These results suggest that even students who did not gain in terms of grades felt that the lab revision pedagogies were helpful to their learning. The opinions of these students regarding how the changes impacted their perceived learning was an important indicator of the success of the revision. A positive perception, or satisfaction with a learning strategy, is viewed as an output variable in measuring student motivation and volition since it is affected by various environmental, psychological, sociological, and genetic factors (Keller, 1999). Satisfaction, or a positive perception, considers how well a student performs on assessments as well as the student’s mental evaluation of his achieved performance based on the difference between the current and desired levels of performance. Using a subgroup of students that are repeating the course to gauge student perceptions is limited by the fact that these students are reviewing material that they have been previously exposed to. Rehearsal, hearing information multiple times in different modes has been shown to promote learning (Evans and Cuffe 2009, Pintrich et al. 1993). The recognition by these students that the pedagogies used in the lab revision were beneficial to them supports the idea that active learning, context and formative assessments could help students who struggle in the anatomy lab.

Formative feedback has been shown to be important in developing learners who are self-regulated and motivated to learn (Clark 2012, Nicol 2006). In fact, formative evaluation is one of the most powerful strategies to increase student learning (Hattie 2009). Formative assessment allows the student to monitor what content they have mastered and where they need to spend more time. It provides a gauge to when the student “is ready” to take an exam or achieve a goal and empowers students to develop learning strategies (Dick 2006). Formative assessment is a significant tool that enhances student achievement (Marzano et al. 2001). The use of E-texts and e-materials for added practice and formative assessment provided formative assessment that promoted student learning in the scientific lab setting. E-texts make the textbook dynamic with interactive diagrams, videos, and adaptive learning programs. Homework assignments were easily created in the framework of the e-materials that offered unending practice with immediate formative feedback. Computer assisted feedback are less intimidating to the student and offer remediation for questions missed (Bloks et al. 2006). The majority of our anatomy and physiology students found value in these resources, but repeating students found them to be of a higher value.

Providing context for content was another beneficial attribute of the revision to the student. Context gives students a desire to learn and understand why content is important (Rizzolo et al. 2010). Context can be as easy as sequencing the learning of bone markings and origins and insertions of muscles together so that students can see why they need to learn the knobs, nooks and holes in bones. Context is also provided in clinical case studies where anatomy has names, faces and stories attached so that students form emotional bonds with the information. Making emotional attachment with content forms more lasting memories and leads to greater retrieval (Barbas, 2000). Bockers et al. (2014) found that providing practical application of anatomy through the context of the clinical setting increased motivation and course grades. Students repeating the anatomy lab found context and sequencing useful to learning in the anatomy and physiology lab (Table 6).

Active learning has been shown to improve student performance in introductory biology courses (Chickering and Gamson 1987, Freeman et al. 2011 and 2014). Engagement promotes student learning (Huang and Carroll 1997, Rao and DiCarlo 2001). With this in mind, we sought to introduce active, hands-on learning in the anatomy and physiology revision. We also employed a system that would involve every student versus an alternative where multiple students observed one student engage in an active learning exercise. Without a cadaver lab where students could learn from an actual human body, several options of models and modeling were available (Krontires-Litowit 2003, Lombardi et al. 2014, McMenamin 2008).

The Anatomy in Clay System® was adopted because it offered individual students the opportunity to create physical models continued on next page
of the structures in the human body on a 15-inch plastic skeleton model. One-time cost and lack of consumables made this an economical option for the lab. In addition, concepts such as variations of human structure could also be emphasized since no two models created would be exactly the same. Use of clay modeling was the preferred technique of learning anatomy in a study conducted by DeHoff et al. (2011) and has been used successfully in large community colleges (Haspel et al. 2013).

Scores on learning outcomes were higher in students using the clay modeling methods (DeHoff et al. 2011). Our findings were similar, where students had a high perception of hands-on learning, using the clay to model human anatomy. Criticisms of the method by students largely pertained to the tactile feel of the clay on the students' hands. Pedagogy became stronger when hands-on activities were enhanced with case studies to add context. Establishing relevance, such as in the use of case studies, can be an important motivational factor to student learning (Kember et al. 2008).

Conclusions
Drake and Pawlina, (2013) called for the formulation of a multimodal model of the anatomy lab to enhance learning for all students. The lab revision in this study meets this request. Combining formative assessment, hands-on learning, and context provided a laboratory experience that increased student success as measured by increase in students earning B and C grades and declining numbers of students earning Ds and Fs. Students repeating the course under the new format after having failed in their initial attempt under the traditional format reported significantly higher perceptions of new learning and pedagogical environment compared to students enrolled the revised course for the first time. The revised anatomy and physiology lab should make success in anatomy lab more attainable.

Literature Cited


The Contralesional Repair Mechanism That Leads to the Recovery of Motor Function After Ischemia in the Primary Motor Cortex

Michael P Lembotesis¹, Brie Paddock PhD², Sarah Cooper MEd³
¹Arcadia University, PA Program, 450 S. Easton Road, Glenside, PA 19038
²,³Arcadia University, Department of Biology, 450 S. Easton Road, Glenside, PA 19038
mlembotesis@arcadia.edu, paddockb@arcadia.edu, cooper@arcadia.edu

Abstract
Ischemia affecting the primary motor cortex (M1) is among the most prevalent causes of long-term motor function impairment in humans. Although victims of ischemic stroke in the M1 usually face challenges executing motor movements for the rest of their lives, motor function recovery has been observed. Advanced brain mapping techniques have revealed multiple mechanisms of brain reorganization after ischemia which lead to the restoration of lost motor functions. This article examines the controversial contralesional (ipsilateral) mechanism that results in a strengthened ipsilateral motor pathway, allowing the unaffected M1 to gain control over lost motor functions. Improved understanding of this mechanism could give rise to gene therapies and other clinical treatments which could change the future of stroke treatment by aiming at increasing NT-3 levels after ischemia in order to further promote neuroplasticity, and thus the chance of functional recovery. doi: 10.21692/haps.2017.011

Key Words: contralesional mechanism, M1, ischemic stroke, motor function, disability, aneurysm

Introduction
In the United States, someone has a stroke every forty seconds and someone dies as a result of a stroke every two minutes (American Stroke Association, ASA 2017, Mozaffarian et al. 2016). This equates to more than 795,000 strokes per year in the US, approximately 130,000 of which lead to fatalities (CDC, NCHS, 2015). Although the number of deaths due to strokes declined 11.3% from 2004 to 2014, stroke remains the fifth leading cause of death in the US behind heart disease, cancer, lower respiratory disease and accidents (ASA 2017, Mozaffarian et al. 2016). Stroke is also the most common cause of long-term disability such as impaired motor function, difficulty perceiving sensory information, trouble producing and understanding language, memory loss or emotional instability (Adamson et al. 2004). Impaired motor function can present as difficulty with movement or maintaining balance, and/or paralysis of certain body regions or extremities (ASA, 2017).

The type and severity of disability depend on the degree of damage and the area of the brain affected by the stroke. Strokes are classified as either hemorrhagic or ischemic depending on how they are caused. There are two primary types of hemorrhagic strokes: those that are caused by an aneurysm and those that are caused by an arteriovenous malformation. An aneurysm is a weak area in a blood vessel that can rupture as a result of high blood pressure. The amount of damage is related to the amount of blood that flows out of the vessel into brain tissue (ASA 2017, Silva et al. 2011). An arteriovenous malformation (AVM) is an abnormal tangle of blood vessels that diverts blood unnaturally from arteries to veins without going through a capillary system. The vessels of an AVM can weaken and dilate over time and if they rupture or leak the result is an intracranial hemorrhage (ASA 2017). In both circumstances, blood is accumulating in the brain, which puts pressure on the nearby neuronal cells, ultimately damaging them (Aiyagari and Gorelick 2016). Blood can also irritate and damage normal blood vessels causing vasoconstriction, which can interrupt normal blood flow to the brain, the result of which is ischemia (ASA 2017, Silva et al. 2011).

Ischemic strokes, which account for about 87% of all strokes, are caused by an occlusion in the blood vessels supplying the brain (ASA 2017, Silva et al. 2011). Occlusions are usually related to fatty atherosclerotic plaques that build up on the inner walls of blood vessels and are of two primary types. A cerebral thrombosis is a blood clot that develops in the region where a vessel is clogged (ASA 2017, Silva et al. 2011). A cerebral embolism typically refers to a blood clot that has formed in the heart or the great vessels of the chest or neck and ultimately breaks apart (ASA 2017). When small pieces of a larger clot or pieces of fat from fatty plaque break loose and get into the narrow vessels of the brain, they form an occlusion (Brainin and Heiss 2014).

Any obstruction in a blood vessel that blocks blood flow to areas of the brain results in neural cell and tissue death due to a lack of oxygen and glucose. Neuronal cell death during ischemia is the result of cellular apoptosis due to mechanisms triggered by the lack of oxygen and glucose and controlled by oxidative metabolism and mitochondrial activities (Sims and Muyderman 2010). Once neuronal cell and tissue death occur, the tissue is no longer functional because the neurons have lost the ability to communicate with each other. As a result, signal transduction is interrupted, which causes the impairment or total loss of the normal function in the affected area (Brainin and Heiss 2014). Neuronal tissue death is
permanent and there is currently no cure for strokes. However, the introduction of clot-destroying drugs, when administered quickly, has contributed to decreasing the number of stroke deaths and long-term disabilities. Unfortunately, these drugs are only useful in ischemic strokes caused by a thrombus since they work by breaking apart the blood cells forming a clot (Moore 1999).

Many types of pathologies can give rise to ischemic strokes. In most cases these pathologies are well understood; they include an array of cardiogenic, atherosclerotic and lacunar (penetrating vessel) conditions (Figure 1). The etiology of ischemic strokes remains unknown in 25 to 39% of cases. Strokes of unknown origin are classified as cryptogenic strokes (Grau 2001, Sliva et al. 2011).

Diagnostic and prognostic information for post-stroke patient care are related to the size and placement of the core and the penumbra of the stroke. The core of the stroke is the irrevocably injured ischemic region of the brain located where the stroke originated. The penumbra is the inadequately perfused area of the brain surrounding the core, which may have the ability to recover if perfusion can be restored quickly (Figure 2) (Sliva et al. 2011). For example, in cases of an occlusion in the middle cerebral artery (MCA) collateral circulation provided by the anterior cerebral artery (ACA) and the posterior cerebral artery (PCA) via the Circle of Willis, or communication among small pial vessels of the surface of the brain, may help to compensate for an occlusion in the larger vessel (Figure 3). The amount of blood flow through collateral systems ultimately determines the overall size of the core and the penumbra. If the occlusion cannot be removed, the core area typically increases in size while the size of the penumbra can be expected to decrease over time. The rate at which the core and the penumbra change shape and size over time is related to the amount of collateral circulation that is available (Silva et al. 2011).
The single greatest risk factor for ischemic stroke occurs in people who have experienced transient ischemic attacks or in those who have previously experienced a stroke. Other risk factors include stenosis of the carotid artery, atrial fibrillation, hypertension, cigarette smoking, diabetes mellitus, sickle cell disease, physical inactivity and obesity. Less well-documented risks include excessive use of alcohol, drug use, elevated lipoprotein, use of oral contraceptives, sleep apnea, migraines, and inflammation (Grau 2001, Silva et al. 2011). Globally, hypertension remains the most significant risk for both ischemic and hemorrhagic stroke due to the roll it plays in cardiovascular pathologies including atherosclerosis of the aorta and cerebral arteries and coronary artery disease. Treating high blood pressure significantly reduces the risk of stroke in people who suffer from hypertension (Grau 2001, Silva et al. 2011).

Ischemia of the Primary Motor Cortex
The ACA and the middle cerebral artery (MCA) both deliver blood to the primary motor cortex (M1). The majority of the M1 is perfused by the MCA while the ACA primarily supplies blood to the most medial area of the M1, which corresponds to leg movement (Ugur et al. 2005). The type of motor function impairment experienced by the patient can pinpoint the location of an occlusion. For example, ischemia due to an occlusion in the ACA is usually observed as a loss of control over leg and hip movements (Rea 2015). However, since the MCA supplies many more areas of the primary motor cortex, the effects of ischemia in this artery can be much more widespread and can include paralysis or weakness of one entire side of the body. If the occlusion causes a blockage before the MCA branches off towards specialized areas of the brain motor impairment will be widespread. If the blockage occurs after the branching of the MCA, only specific motor functions will be affected (Picelli et al. 2017).

Recovery of Motor Function After Ischemia
Although many who suffer from ischemia of the M1 will experience motor function impairment for the rest of their lives, recovery has occasionally been observed (Pantano et al. 1996). Recovery after ischemia affecting the M1 can be defined as regaining control over impaired muscle movements. However, recovery is not an all-or-none process. As a result, victims of M1 ischemia may experience motor function recovery to various degrees in which all, or only some, function is restored. In order to assess the recovery of motor function, victims of M1 ischemia are evaluated using the Modified Rankin Scale (MRS) (Table 1) and the Barthel Index (BI) (Table 2) which both quantitate the level of motor function impairment (Sutter et al. 1999). The Modified Rankin Scale measures an individual’s overall motor disability while the Barthel Index measures an individual’s ability to execute daily activities (Van Swieten et al. 1988, D’Olhaberriague et al. 1996). The MRS and BI are conducted shortly after ischemia and repeated periodically to gauge the amount of motor function recovery (Nunn et al. 2016).

### Table 1. The modified Rankin Scale is used to measure an individual’s overall motor disability.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No symptoms</td>
</tr>
<tr>
<td>1</td>
<td>No significant disability, despite symptoms; able to perform all usual duties and activities</td>
</tr>
<tr>
<td>2</td>
<td>Slight disability; unable to perform all previous activities but able to look after own affairs without assistance</td>
</tr>
<tr>
<td>3</td>
<td>Moderate disability; requires some help, but able to walk without assistance</td>
</tr>
<tr>
<td>4</td>
<td>Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance</td>
</tr>
<tr>
<td>5</td>
<td>Severe disability; bedridden, incontinent, and requires constant nursing care and attention</td>
</tr>
</tbody>
</table>

### Table 2. The Barthel Index is used to measure an individual’s ability to execute daily activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding</td>
<td></td>
</tr>
<tr>
<td>0 = unable</td>
<td></td>
</tr>
<tr>
<td>5 = need cutting, spreading butter, etc, or requires modified diet</td>
<td></td>
</tr>
<tr>
<td>10 = independent</td>
<td></td>
</tr>
<tr>
<td>Bathing</td>
<td></td>
</tr>
<tr>
<td>0 = dependent</td>
<td></td>
</tr>
<tr>
<td>5 = independent (or in shower)</td>
<td></td>
</tr>
<tr>
<td>Grooming</td>
<td></td>
</tr>
<tr>
<td>0 = need help with personal care</td>
<td></td>
</tr>
<tr>
<td>5 = independent (or in shower)</td>
<td></td>
</tr>
<tr>
<td>Dressing</td>
<td></td>
</tr>
<tr>
<td>0 = dependent</td>
<td></td>
</tr>
<tr>
<td>5 = needs help but can do about half unaided</td>
<td></td>
</tr>
<tr>
<td>10 = independent (including buttons, zippers, etc)</td>
<td></td>
</tr>
<tr>
<td>Bowels</td>
<td></td>
</tr>
<tr>
<td>0 = incontinence (or needs to be given enemas)</td>
<td></td>
</tr>
<tr>
<td>5 = occasional accident</td>
<td></td>
</tr>
<tr>
<td>10 =continent</td>
<td></td>
</tr>
<tr>
<td>Bladder</td>
<td></td>
</tr>
<tr>
<td>0 = incontinence, or catheterised and unable to manage alone</td>
<td></td>
</tr>
<tr>
<td>5 = occasional accident</td>
<td></td>
</tr>
<tr>
<td>10 =continent</td>
<td></td>
</tr>
<tr>
<td>Toilet use</td>
<td></td>
</tr>
<tr>
<td>0 = dependent</td>
<td></td>
</tr>
<tr>
<td>5 = needs some help, but can do something alone</td>
<td></td>
</tr>
<tr>
<td>10 = independent (on and off, dressing, wiping)</td>
<td></td>
</tr>
<tr>
<td>Transfers (bed to chair and back)</td>
<td></td>
</tr>
<tr>
<td>0 = unable, no sitting balance</td>
<td></td>
</tr>
<tr>
<td>5 = major help (one or two people, physical)</td>
<td></td>
</tr>
<tr>
<td>10 = minor help (verbally or physical)</td>
<td></td>
</tr>
<tr>
<td>15 = independent</td>
<td></td>
</tr>
<tr>
<td>Mobility (on level surfaces)</td>
<td></td>
</tr>
<tr>
<td>0 = immobile or ≥5 yards</td>
<td></td>
</tr>
<tr>
<td>5 = wheelchair independent, including comas, ≥50 yards</td>
<td></td>
</tr>
<tr>
<td>10 = walks with help of one person (verbally or physical) ≥50 yards</td>
<td></td>
</tr>
<tr>
<td>15 = independent (but may use any aid, ag. stick) ≥50 yards</td>
<td></td>
</tr>
<tr>
<td>Stairs</td>
<td></td>
</tr>
<tr>
<td>0 = unable</td>
<td></td>
</tr>
<tr>
<td>5 = needs help (verbally, physical, carrying aid)</td>
<td></td>
</tr>
<tr>
<td>10 = independent</td>
<td></td>
</tr>
</tbody>
</table>

Total (0–100)
In addition to the MRS and BI, which measure recovery at the functional level, advancements in brain imaging technologies have made it possible to observe recovery at the tissue level by revealing changes in neuronal pathways within the brain (Jang 2011). Changes in the brain at the cellular and tissue levels lead to the formation of new or strengthened motor pathways that make the recovery of motor function possible (Hallett 2001). Brain imaging is repeated frequently and paired with the MRS and BI measurements to observe how changes in neuronal pathways after ischemia correspond to recovery (Nunn et al. 2016). The implementation of these techniques has revealed that functional recovery occurs due to the reorganization of motor pathways (Langhorne et al. 2009). To confirm this, structural Magnetic Resonance Imaging (MRI) and resting state functional MRI (rsfMRI) are used to observe changes in functional brain connectivity of the affected M1 regions (Van Den Huevel 2010). While structural MRIs reveal the anatomy of the brain, rsfMRIs display the level of resting-state brain activity by monitoring changes in blood flow (Edelman and Warach 1993, Huettel et al. 2004). However, when structural and functional MRIs are combined using computer software, the resulting image shows the resting state functional connectivity (rsFC) between specific brain tissues based on the brain activity observed between the tissues (Van Den Huevel 2010). Although some level of brain activity is always present in the resting state, increased activity levels correspond to increased brain connectivity due to new or strengthened neuronal pathways that have formed in response to ischemia. New or strengthened motor pathways after ischemia allow for the reconnection of the M1 to the affected motor unit, which results in the restoration of motor functions (Hallett 2001).

**Neuroplasticity and Brain Reorganization**

Brain reorganization in the form of new or strengthened motor pathways is dependent upon neuroplasticity, which is the brain’s ability to change in response to trauma, such as ischemia, without regenerating cells or tissues (Cramer and Riley 2008). Unlike other tissues of the body that are able to use mitosis to regenerate, brain tissue lacks this ability due to the loss of centrioles in neurons (Siegelbaum and Hudspeth 2000). Instead, neurons respond to trauma by exhibiting plasticity, which is the ability to reorganize synapses and neuronal pathways via axonal and dendrite migration (Oliveira et al. 2013). After ischemia of the M1, neuroplasticity promotes the dendrites and axons of M1 neurons to migrate, forming new synapses that create a new pathway for signal transduction. These new pathways can restore the connection between the M1 and the affected motor functions by allowing signal transduction to bypass the damaged brain tissue. Motor function is regained by restoring functional connectivity (Cramer and Riley 2008, Langhorne et al. 2009). The mechanisms that promote neuroplasticity after brain tissue damage are still unknown, however, increasing evidence suggests that neurotrophins are the brain signals responsible for increasing axonal migration abilities of neurons, and thus neuroplasticity (Oliveira et al. 2013).

**Neurotrophins and Neuroplasticity**

It has been proposed that signaling via neurotrophins is the likely mechanism by which plasticity is stimulated in neurons after ischemia. Neurotrophins are also believed to be responsible for transmitting signals that govern neuronal cell fate throughout the brain (Skaper 2012). Neurotrophins are a family of proteins that are classified as growth factors specific to nervous system development (Oliveira et al. 2013). It has been demonstrated that neurotrophins, such as nerve growth factor (NGF), play a role in molding neural tissues throughout development by promoting cell survival and proliferation (Bouzas-Rodriguez et al. 2010). Some neurotrophins promote cell growth, while others, such as brain-derived neurotrophic factor (BDNF), have the ability to prevent neuronal apoptosis (Bouzas-Rodriguez et al. 2010). Although BDNF may serve an important role in minimizing neuronal apoptosis during ischemia, it has not been linked to promoting neuroplasticity after ischemia (Oliveira et al. 2013). However, it has been demonstrated that neurophin-3 (NT-3) promotes axonal migration in damaged spinal cords of mice (Yang et al. 2009). Evidence of NT-3 promoting neuroplasticity in the spinal cord suggests that NT-3 is likely the neurophin responsible for increased neuroplasticity in the brain after ischemia, however, this has yet to be tested (Kamei et al. 2007). The binding of neurotrophins to their respective receptors allows them to have an effect on neuron characteristics and capabilities (Roux and Barker 2002). Before neurotrophins can bind to receptors, they must be produced in neurons and then released when specific signals are received. Although these signals have yet to be determined, it has been proposed that they can be generated as a result of brain trauma (Boon and Vickers 2013). From this, it can be inferred that signals generated by ischemia increase the production and release of NT-3 which then binds with tropomyosin receptor kinase C (TrkC), promoting migration abilities of axons and dendrites (Zhou et al. 2003).

**Mechanisms for Recovery After Ischemia of the Primary Motor Cortex**

The migration of axons and dendrites in the M1 after ischemia is the primary principle related to brain reorganization, which leads to the recovery of motor functions. However, advanced brain imaging techniques have revealed that the reorganization of neural pathways, which reestablish functional connectivity and motor function after ischemia, can occur by way of three general mechanisms (Jang 2011). One way in which motor function can be recovered after ischemia depends on the recovery of the damaged areas of the lateral corticospinal tract. This mechanism of recovery is the result of increased connectivity in the descending motor pathway that was damaged by the lesion. Increased neuroplasticity enhances the functional connectivity between the affected M1 regions and the normal corticospinal tract. This results in a strengthened motor pathway to the affected muscles, resulting in the improvement of motor function (Stinear et al. 2007). However, since this mechanism of

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recovery relies on the original motor pathway to reestablish control of motor function, it is thought to occur only when damage to the cortical area is minimal (Ward and Cohen 2004).

In another mechanism, the subcortical perilesional reorganization mechanism, motor function is restored by increased connectivity between the subcortical areas around the lesion site and the affected motor pathway. The subregion of the motor region normally moderates voluntary motor functions and carries out instinctive movements. However, in this mechanism of reorganization, the subcortical area gains control over the motor functions that have been affected by the lesion (Yong-Hyun 2007). Studies observing this mechanism of repair have found that there is a decrease in the amount of myelinated axons in the cortical site, followed by an increase in the amount of myelinated axons in the subcortical regions near the lesion site. This increase in white matter within the subcortical areas is thought to provide enhanced connectivity and control over the affected motor pathway (Jang 2011).

Recovery of Motor Functions via Contralesional Reorganization

Unlike the first two mechanisms of motor function recovery, which occur in the ipsilesional hemisphere, the third mechanism, reorganization via the ipsilateral motor pathway, takes place in the contralesional hemisphere. In this mechanism the unaffected hemisphere gains control over the affected motor functions that are located on the same side of the body (Jang 2009). To accomplish this, the axons and dendrites of neurons in the contralesional M1 migrate to increase connectivity between the contralesional M1 and the existing ipsilateral motor pathway, which under normal circumstances has minimal control over the motor functions on the same side of the body (Jang 2012). However, the ipsilateral motor pathway can be expanded and strengthened as axons and dendrites migrate into it. As functional connectivity continues to increase between the contralesional M1 and the ipsilateral motor pathway, a signal transduction pathway capable of exciting the affected muscle tissues is formed. As a result, the contralesional M1 gains control over the impaired motor functions (Ward and Cohen 2004).

The contralesional mechanism of repair is thought to occur when the damage caused by ischemia is so severe that repair via mechanisms of the ipsilesional hemisphere are not possible (Jang 2012). After severe ischemic events, it is likely that the lesion is large enough to include all motor pathways extending from the M1 and subcortical regions, making it impossible for the brain to strengthen these pathways (Jang 2012). Instead, neuroplasticity of the contralesional hemisphere allows the undamaged M1 to gain control over the affected motor functions by expanding the M1’s existing connection to the affected motor pathway (Ward and Cohen 2004). Ischemic events that are severe enough to warrant contralesional repair are most likely paired with total motor function loss, resulting in paralysis of large muscle groups (Brainin and Heiss 2014).

In recent years, contralesional repair has been the focus of studies aimed at uncovering the processes that occur after ischemia and although it has been generally accepted as a repair mechanism in mice, it has yet to be demonstrated as a recovery mechanism in humans (Jang 2009). This dispute is partially due to previous studies that have concluded that contralesional repair is not an effective mechanism for restoring lost motor functions and results in poor functional recovery (Kim et al. 2004). However, this conclusion is challenged by the theory that contralesional repair sometimes occurs simultaneously with another repair mechanism or when motor function is not completely lost due to ischemia. Both circumstances result in poor motor function recovery due to the presence of more than one motor pathway to affected motor functions that conflict with each other. As a result, contralesional repair appears to be an ineffective recovery mechanism even though its success is dependent upon additional factors. In addition, the signaling pathway that promotes contralesional neuroplasticity is still unknown (Hua et al. 2015). However, evidence of NT-3 leading to neuroplasticity after spinal cord damage has led researchers to propose that NT-3 and its unknown mechanism of release play an important role in motor function recovery after M1 ischemia via contralesional repair (Hua et al. 2015).

Current Studies that Support Contralesional M1 repair

Increased functional connectivity in the contralesional M1 after ischemia occurs in humans and can lead to recovery

Although motor function recovery due to increased functional connectivity in the contralesional M1 has only been demonstrated in mice (Jang 2012), evidence now supports the claim that this process also occurs after ischemia in humans and plays an important role in preserving or restoring motor function. In support of this claim, Almeida et al. (2017) described their study of 59 individuals recovering from ischemic stroke. This study demonstrated increased functional connectivity observed in the contralesional M1 of all of the ischemic stroke participants, which suggested that motor pathways in the contralesional M1 were expanded (Ward and Cohen 2004). In light of previous studies that have supported the view that expanded or strengthened motor pathways allow for the restoration of motor function after M1 ischemia, it can be concluded that the observed increase in contralesional M1 connectivity contributed to functional recovery (Langhorne et al. 2009). After ischemia, increased functional connectivity in the contralesional M1 via expanded ipsilateral motor pathways facilitates functional recovery by reestablishing the signal transduction pathway from the motor cortex to the affected motor units (Langhorne et al. 2009). However, this study is limited because no two ischemic events are exactly the same and measuring the

continued on next page
functional connectivity between the contralesional M1 and the ipsilateral motor pathway of each affected motor function for every participant is unrealistic.

**Increased contralesional connectivity occurs in response to the ischemic event**

In addition, it can be concluded that the signal that initiates the contralesional repair mechanism is released by the ischemic event itself, rather than a signal resulting from motor function loss (Almeida et al. 2017). The finding that increased functional connectivity in the contralesional M1 occurred in all stroke participants in this study supports this, regardless of whether they experienced motor function impairment after ischemia. Although it is thought that contralesional repair only occurs when damage due to ischemia is severe, this theory is challenged due to the increase in contralesional connectivity of stroke participants who had no motor function impairment. As a result, contralesional repair appears to exist as a default response to ischemia, which may also help to explain why contralesional repair is sometimes believed to be an ineffective mechanism of recovery. If contralesional connectivity always increases in response to an ischemic event, even when the damage to the affected M1 is not severe enough, there is the potential for conflicting motor pathways, which results in decreased motor function (Jang 2012).

**Exposure to miRNA-132 Up-regulates Genes Responsible for Neuroplasticity via ERK Signaling Pathway**

Although the signal released by ischemia that leads to increased contralesional connectivity is unknown, it has been demonstrated that Micro-RNAs (miRNAs) are released during cellular apoptosis and have the ability to travel extracellularly to other tissues or regions of the body (Turchinovich et al. 2011). Interestingly, miRNA-132 was found to increase the plasticity of neural cells, which is thought to cause the observed increase in contralesional functional connectivity. Due to miRNA-132’s role in promoting neuroplasticity, it is likely that miRNA-132 is the signal released by ischemia when neurons undergo cellular apoptosis due to the lack of glucose and oxygen (Sims and Muyderman 2010).

A study done by Dmitrieva et al. in 2016 examined how ischemia affects the expression of specific genes that code for the production of various neurotrophins and their receptors. The study revealed that the expression of certain neurotrophic genes is up-regulated in various parts of the brain in response to ischemia. It is well known that miRNAs play an important role in gene regulation, however, they are primarily associated with down-regulating gene expression since they function by binding to mRNA and blocking translation or targeting the mRNA for destruction (He and Hannon 2004). However, when mouse brain neuroblastoma cells (NB41A3) were exposed to miRNA-132, an increase in NT-3 gene expression was observed which suggests that miRNAs are capable of regulating gene expression through more than one mechanism. The western blot assay and the use of a known inhibitor of the Extracellular-signal-Regulated Kinase (ERK), which prevented the up-regulation of NT-3, revealed that up-regulation occurred via the ERK signaling pathway. These findings are supported by additional studies which have also found that miRNAs are capable of up-regulating gene expression through the ERK signaling pathway (Kosik 2006, Liu and Wilson 2012).

**Up-regulated expression of NT-3 & TrkC promotes neuroplasticity in the contralesional M1**

In an attempt to better understand how NT-3 expression is increased and the effect it has on neurons, Ge et al. (2016) investigated the result of transfecting neuroblastoma cells (NB41A3) with micro RNA-132 (miR-132), which is believed to lead to neuronal cell migration, growth, and proliferation (Wanet et al. 2012). Micro-RNAs are tiny fragments of RNA that are capable of regulating the expression of genes by binding to messenger RNAs (mRNAs) that encode proteins (He and Hannon 2004). This study also examined the effect that miR-132 had on NT-3 expression levels since previous studies involving spinal cord injury in rats have suggested that NT-3 promotes neuroplasticity by increasing axonal and dendritic migration abilities (Grill et al. 1997).

Ge et al. offered evidence supporting the supposition that the up-regulation of NT-3 expression facilitates neuroplasticity in mouse brain neuroblastoma cells (NB41A3). In this study the up-regulation of NT-3 in NB41A3 cells was demonstrated to promote neuroplasticity by increasing the migration abilities of axons and dendrites, similarly to how NT-3 promotes neuroplasticity in damaged spinal nerves (Kamei et al. 2007). From this, it can be concluded that NT-3 is the growth factor specific to the nervous system that increases the ability of neurons to migrate and form new synaptic connections after damage.

In addition, the increased expression of genes encoding for NT-3 and TrkC observed in the contralesional cortex after ischemia in rats can be used to explain the increased contralesional functional connectivity observed in all stroke participants. Since NT-3 has been linked to neuroplasticity, the up-regulation of NT-3 and its receptor (TrkC) in the contralesional hemisphere can be attributed to promoting the expansion of existing motor pathways in this region of the brain. This is important because it can now be concluded that NT-3 is responsible for promoting the expansion of motor pathways that leads to motor function recovery.

**Conclusion**

**Proposed Mechanism of Contralesional Repair Leading to Functional Recovery**

Based on a compilation of the current information, the role of NT-3 and the mechanism that leads to the recovery of motor function after ischemia via contralesional repair can be inferred. When an occlusion occurs in the anterior
cerebral artery or the middle cerebral artery, the neurons in the M1 experience changes in oxidative metabolism and mitochondrial activities, which causes the neurons to undergo apoptosis. During apoptosis, specific miRNAs such as miR-132 are packaged into membrane bound vesicles known as microparticles or apoptotic bodies and are released once blebbing of the plasma membrane occurs (Majno and Joris 1995). Once released, the vesicles containing miR-132 are able to travel extracellularly throughout the brain, including the contralesional hemisphere. The miR-132 then signals nearby neurons to up-regulate the expression of NT-3 and its receptor TrkC via the ERK signaling pathway. This causes NT-3 to be produced inside contralesional M1 neurons and then released to bind with its receptor TrkC located on its membrane surface, as well as the surface of nearby neurons. The increase in the amount of TrkC bound by NT-3 signals for the promotion of neuroplasticity by increasing the migration abilities of axons and dendrites (Lamballe et al. 1991). The increased neuroplasticity allows neurons to form new synaptic connections. In the contralesional M1, the expansion of the ipsilateral motor pathway, due to the gathering of additional axons, allows for a signal transduction pathway to be reestablished between the contralesional M1 and the motor units affected by ischemia. Further strengthening of this pathway, due to neuronal migration, results in increased functional connectivity between the contralesional M1 and the affected motor unit. This increased functional connectivity of the ipsilateral motor pathway allows the contralesional M1 to gain control over the affected motor functions. Although the ipsilateral motor pathway normally has little to no control over the affected motor functions, the strengthening of these pathways can lead to the restoration of motor function.

Suggestions for Future Studies
Due to its controversial status, future studies should focus on observing the contralesional repair mechanism after ischemia to determine if it will be generally accepted as a successful mechanism for restoring motor function in humans. Additionally, the proposed mechanism of contralesional repair should be tested further in order to support or refute it. In order to better understand the contralesional repair mechanism, research should focus on uncovering the signal that attracts axons to migrate towards specific motor pathways. It would also be beneficial to take a closer look at the function of each neurotrophin in order to determine if it plays a role in promoting neuroplasticity after ischemia. For example, BDNF has been shown to prevent neuronal apoptosis, however, it has yet to be supported that BDNF is able to prevent apoptosis due to ischemia (Kubo et al. 1995). Similarly, NGF has been shown to promote nerve growth, however, it is unclear whether NGF contributes to neuroplasticity after ischemia (Maisonpierre et al. 1990). Uncovering the function of each neurotrophin in response to ischemia will provide a better understanding of what the neurons in each region of the brain were being instructed to do via changes in gene expression.

Impact of Findings on Studies Regarding Ischemia
According to the Center for Disease Control (CDC), more than 50% of stroke victims over the age of 65 will be challenged with impairment of motor function (Mozaffarian et al. 2015). Due to the large numbers of people who suffer from ischemia of the M1, the current findings are tremendously important and provide hope that further research of the recovery mechanisms will lead to a cure for strokes. Our increased understanding of the contralesional mechanism may provide a better understanding of all mechanisms of repair after ischemia, including those pertaining to non-M1 ischemia, since it is likely that they share a similar pathway that leads to increased neuroplasticity.

About the Authors
Michael Lembotesis graduated from Arcadia University with a Bachelor of Arts in Biology in the spring of 2017. He is continuing on at Arcadia to pursue a Master’s degree in Physician Assistant Studies and is expected to graduate in the spring of 2019.

Brie Paddock, PhD is an assistant professor of Biology at Arcadia University. Her research lab investigates the pathogenesis of Alzheimer’s Disease using a Drosophila model. She teaches Comparative Anatomy and Physiology, Human Physiology and Advanced Physiology and she serves as the Chair of the Biology Department Curriculum Committee.

Sarah Cooper is an Associate Professor of Biology at Arcadia University and Editor-in-Chief of the HAPS Educator. She has taught human anatomy and general biology at Arcadia University since 1981. She is the pre-nursing adviser and the coordinator of the interdisciplinary science courses at Arcadia and she has served as a member of the Arcadia University Judicial Board since 1984.

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Kelly Paralis, Owner
Penumbra Design, Inc.
143 North Sylvania Avenue, First Floor
Rockledge, PA 19064
Tel: 215-379-2832

Literature cited


The Possible Effects of Non-steroidal Anti-inflammatory Drugs (NSAIDs) on the COX-2 Pathway of Skeletal Muscle Repair

Megan Obarowski¹, Sarah Cooper MEd², John Daley PhD³, and Randy Tammara, PharmD⁴

¹Gwynedd Mercy University, Accelerated BSN Program, 1325 Sumneytown Pike, Gwynedd Valley, PA
²,³Arcadia University, Department of Biology, 450 South Easton Road, Glenside, PA 19038
⁴Arcadia University, Masters in Public Health Program, 450 South Easton Road, Glenside, PA 19038
mobarowski@arcadia.edu, coopers@arcadia.edu, daleyj@arcadia.edu, rantam111@gmail.com

Abstract

Non-steroidal anti-inflammatory drugs (NSAIDs) are thought to play a role in the process of muscle repair. However, the mechanism by which they function remains poorly understood. Recent studies have focused on the link between the COX-2 pathway of muscle repair and anti-inflammatory drugs. This article examines representative studies by Oak et al. (2014) and Lu et al. (2015), who have investigated this process in-depth and found differing results regarding the effects of COX inhibitors on the repair of skeletal muscle after injury. These studies also demonstrate that NSAIDs operate within the COX-2 pathway, which is a necessary pathway for muscle repair. doi: 10.21692/haps.2017.012

Key Words: Non-steroidal anti-inflammatory (NSAIDs), COX-1, COX-2, sports-related injury, muscle repair

Introduction

Non-steroidal anti-inflammatory drugs (NSAIDs) are among the most commonly used pain relief medications in the world. More than 30 million Americans use NSAIDs each day for relief from common discomforts such as headache, arthritis, athletic injuries, tissue swelling and the reduction of fever (American Gastroenterological Association AGA 2017, Schoenfeld 2012). In the United States alone, approximately 30 million children and teenagers participate in organized sports, resulting in 3.5 million sports-related injuries and 775,000 children under the age of 14 treated in hospital emergency rooms each year (Johns Hopkins Health Library 2017). Sprains and strains are the most common sports-related injuries. When an injury such as a sprain or strain occurs, damaged tissues release prostaglandins that cause tissue swelling and amplification of electrical pain signals. NSAIDs block the COX (Cyclooxygenase) -1 and COX-2 enzymes that play an important role in prostaglandin production. The results are less pain and reduced swelling at the site of injury (Bondesen et al. 2004).

There are side effects associated with habitual NSAID use, however, the most common of which are gastrointestinal problems such as ulcers. For example, an array of prostaglandins produced by gastric epithelial cells, which the COX-1 enzyme helps to produce, protects the stomach lining by having stimulatory effects on gastric mucus and bicarbonate production (Wallace 2008). Blocking the COX-1 enzyme by continuous use of NSAIDs slows down the production of this prostaglandin, which may result in an increased rate of acid-induced damage to the tissues of the gastrointestinal tract. NSAIDs can also raise blood pressure by reducing blood flow to the kidneys, which results in fluid build-up in the blood stream and may lead to kidney damage over time (AGA 2017). For reasons that are not yet understood, NSAID use can trigger allergic reactions in certain people who have asthma (AGA 2017). COX-2 inhibitors were designed to alleviate pain while avoiding the gastrointestinal problems associated with other NSAIDs by blocking only the COX-2 enzyme, which is not associated with the production of prostaglandins that protect the lining of the GI tract. However, levels of COX-1 and COX 2 enzymes are normally balanced in the body and blocking only one of them may result in unexpected problems. For example, COX-1 enzymes are responsible for making the prostaglandin derivative thromboxane, which is associated with blood clotting (Caughey et al. 2001). This substance is normally kept in check by prostacyclin, which is synthesized with the help of COX-2 enzymes. When only COX-2 enzymes are blocked, prostacyclin levels decrease while the influence of COX-1 enzymes on thromboxane production continues unchecked causing the risk of heart attack and stroke to increase (Caughey et al. 2001). This risk was considered to be so high that a COX-2 inhibitor known as Vioxx was removed from the market in 2004 (Leshier 2004). Given this history of side effects associated with COX-1 and COX-2 inhibitors, and the prevalence of sports-related injuries, it is not surprising that questions have been raised with respect to the effect of long term NSAID use on muscle repair.

Muscle Injury

The two most common types of muscle injuries are classified as tearing injuries (strains) and in situ necrosis injuries (Järvinen et al. 2013). A tearing injury (strain) occurs when the muscle fiber, the surrounding basal lamina and the neighboring capillaries are all damaged. An in situ necrosis injury can occur, for example, in response to limb compression or the interruption of blood flow by a blood clot; in these situations, the muscle fibers are partially...
necrotized but there is no damage to the basal lamina or the neighboring capillaries (Järvinen et al. 2013). Shearing injuries are the most common type of muscle injury. They are classified as mild, moderate or severe based on the extent of the muscle fiber damage and the size of the hematoma associated with the injury (Järvinen et al. 2013).

Myogenesis
Any type of muscle injury triggers an inflammatory response in the body. Muscle injury results in damage to the cellular make-up of the muscle fiber and the muscle becomes incapable of normal contraction (Järvinen et al. 2013). Muscle regeneration, myogenesis, re-creates a working muscle fiber (Bondesen et al. 2004).

The three phases of the muscle healing are destruction, repair, and remodeling (Järvinen et al. 2013). During the destruction phase, the injured muscle fibers become necrotic. Necrosis is stopped by the formation of a new sarcolemma and the area between the two ends of the new sarcolemma fills with a hematoma. The formation of the hematoma signals the start of the inflammatory response (Järvinen et al. 2013).

During the second phase of the muscle healing process, the repair phase, monocytes and macrophages phagocytize damaged muscle fibers and basal lamina in order to make room for the regeneration of new fibers (Arnold et al. 2007, Järvinen et al. 2013). Following phagocytosis, satellite cells, which are exposed when the basal lamina ruptures, differentiate into myoblasts (Bondesen et al. 2004, Järvinen et al. 2013). Committed stem cells form myoblasts through a direct process, while undifferentiated stem cells produce more stem cells, which are stored in the newly formed muscle (Järvinen et al. 2013). Myoblasts form a myotube that punctures and expands into the scar tissue of the injury. The muscle regains its blood flow as capillaries are replaced (Järvinen et al. 2013).

In the final stage of the process, the remodeling phase, myotubes mature into contractile muscle fibers and newly formed muscle fibers insert themselves into the tendon. A small area of scar tissue remains between the two halves of the newly formed muscle fibers (Järvinen et al. 2013). Each of the three major steps of myogenesis is controlled by different factors such as chemoattractants, growth factors, and prostaglandins (Bondesen et al. 2004).

Prostaglandins
Prostaglandins (PGs) act as modulators of the inflammatory response in muscle tissue and other body tissues. They are also involved in many important stages of myoblast development (Bondesen et al. 2004). Prostaglandins, which are up-regulated when tissue is inflamed, are synthesized when COX enzymes convert arachidonic acid, which is secreted by prostaglandin membranes, into an inactive form of prostaglandin, known as PGH₂ (Bondesen et al. 2004, Ricciotti and FitzGerald 2011). This inactive form is then metabolized into an active form of PGF₂α, PGI₂, or PGD₂ (Ricciotti and FitzGerald 2011, Bondesen et al. 2004). Active prostaglandins are moved out of the cell where they subsequently bind to G-protein coupled receptors or nuclear peroxisomes receptors associated with target cells (Bondesen et al. 2004).

The most abundant PG in the body is PGF₂α, which is involved in producing the typical signs of inflammation such as pain, heat, redness and swelling (Ricciotti and FitzGerald, 2011). PGF₂α acts on the neurons of the spinal cord and brain that cause pain and is found in high concentrations in the synovial fluid. Both isoforms of the COX enzyme, COX-1 and COX-2, catalyze the production of inactive PGH₂, which leads to the production of the same bioactive PGs (Bondesen et al. 2004). The difference between the two isoforms is in the amount of each bioactive prostaglandin that is produced.

Flow chart shows the derivation of five prostaglandins from arachidonic acid in the presence of COX-1 and COX-2. Adapted from Ricciotti and Fitzgerald 2011. Illustration by Kelly Paralis, Penumbra Design, Inc.

NSAIDs
NSAIDs can be bought over the counter at low dosages or prescribed by medical professionals in higher dosages. They can either be selective COX inhibitors or non-selective COX inhibitors. Selective COX inhibitors act on only the COX-2 enzyme. Non-selective COX inhibitors act on both isoforms of the enzyme. Well-known NSAIDs include: ibuprofen, flurbiprofen axetil, celecoxib, and licofelone (Table 1) (Lu et al. 2015, Oak et al. 2014). Ibuprofen is a non-selective COX
inhibitor that is available over the counter. It is used for pain management and inflammation due to muscle injury, headache, or menstrual cramps and to reduce fever. It is also effective in reducing post-operative pain. Flurbiprofen axetil, another nonselective COX inhibitor, is typically administered intravenously by medical professionals (Yamashita et al. 2006). Celecoxib is a selective COX-2 inhibitor that also targets the Na+, K+, and Ca++ channels in muscle cells. It is often used to treat arthritis and acute pain (Frolov et al. 2011).

Recent research that suggested that the protective effects of COX-2 inhibitors might not be as significant as was originally thought, led to the development of a new class of drugs, 5-LOX inhibitors, to control inflammatory diseases (Celotti and Durand 2003). In general, these drugs are formulated as balanced inhibitors of 5-lipoxygenase (5-LOX) and cyclooxygenase (COX-1 and COX -2). 5-LOX inhibitors combined with COX inhibitors block the formation of all the enzymatically arachidonic acid-derived metabolites, both prostaglandins and leukotrienes (Celotti and Durand 2003). These drugs have been shown to possess a high degree of anti-inflammatory efficacy without serious side effects. Licofelone is both a 5-LOX and a non-selective COX inhibitor. It possesses powerful anti-inflammatory, analgesic and anti-asthmatic effects at doses that are low enough to not cause significant gastrointestinal side effects (Celotti and Durand 2003). Any of the NSAIDs can be used for the treatment of pain and inflammation due to muscle injury.

### Table 1. Comparison of Commonly Used NSAIDs and their associated risks.

<table>
<thead>
<tr>
<th>DRUG</th>
<th>COX-2 SELECTIVITY (In vitro)</th>
<th>GI Risk</th>
<th>Cardiovascular Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirin</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Celecoxib (Celebrex)</td>
<td>High</td>
<td>Low</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Diclofenac (Voltaren)</td>
<td>High</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Flurbiprofen (Ansaid)</td>
<td>Low</td>
<td>High</td>
<td>Data not available</td>
</tr>
<tr>
<td>Ibuprofen (Motrin, Advil)</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate to high</td>
</tr>
<tr>
<td>Indomethacin (Indocin)</td>
<td>Low</td>
<td>Moderate to High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Ketoprofen (Onudis)</td>
<td>Low</td>
<td>Moderate</td>
<td>Data not available</td>
</tr>
<tr>
<td>Ketorolac (Toradol)</td>
<td>Low</td>
<td>High</td>
<td>Data not available</td>
</tr>
<tr>
<td>Licofelone</td>
<td>Data not available</td>
<td>Data not available</td>
<td>Data not available</td>
</tr>
<tr>
<td>Meloxicam (Mobic)</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Nabumetone (Relafin)</td>
<td>Moderate</td>
<td>Low</td>
<td>Data not available</td>
</tr>
<tr>
<td>Naproxen (Anaprox DS)</td>
<td>Low</td>
<td>Moderate</td>
<td>Low to Moderate</td>
</tr>
<tr>
<td>Oxaprozin (Daypro)</td>
<td>Low</td>
<td>High</td>
<td>Data not available</td>
</tr>
<tr>
<td>Piroxicam (Feldene)</td>
<td>Moderate</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

The ability of NSAIDs to reduce prostaglandin production has effects within the body in addition to their ability to reduce pain and inflammation (Ricciotti and FitzGerald 2011). Many studies have shown the importance of PGs in the biological processes of healing muscle such as their impact on the activation of the muscle stem cells found in the basal lamina of myofibers, precursor cell activation, myoblast proliferation, myoblast fusion, and the synthesis of muscle proteins (Prisk and Huard 2003, Schoenfield 2012). If NSAIDs are blocking the action of the COX enzyme, one would hypothesize that there will be significant effects on the regeneration of muscle after injury. This has led to additional investigations of the effectiveness of NSAIDs in treating muscle injury.

Recently, a link has been found between COX enzymes and the repair of injured muscle tissue (Oak et al. 2014, Lu et al. 2015). A link has also been found between the COX-2 isoform and NSAIDs suggesting that NSAIDs may have a
complex effect on the healing of muscle injuries characterized by early signs of improvement followed by subsequent late impairment in functional capacity and histology of muscle tissue (Prisk and Huard 2003). Studies are currently investigating the underlying effects this link may have on the regeneration of muscle fibers after injury. With these new findings, questions regarding the efficiency of NSAIDs and the treatment of inflammation associated with muscle injury are being examined (Oak et al. 2014, Lu et al. 2015).

**Link Between the COX-2 pathway and NSAIDs**

Non-steroidal anti-inflammatory drugs are thought to play a role in the process of muscle repair. However, the mechanisms by which they function are poorly understood. Recent studies have focused on the link between the COX-2 pathway of muscle repair and anti-inflammatory drugs. Studies by Oak et al. (2014) and Lu et al. (2015), have examined this process in-depth and found differing results regarding the effects of the COX-2 pathway on the repair of skeletal muscle tissue after injury. These studies also demonstrated that NSAIDs operate within the COX-2 pathway, which is a necessary pathway for muscle regeneration (Oak et al. 2014, Lu et al. 2015).

**COX Inhibitors Improve Healing in Rat Model**

The COX-2 pathway operates as a pro-inflammatory pathway that occurs after a muscle has been injured (BondeSEN et al. 2004). Anti-inflammatory drugs such as NSAIDs target and inhibit this pathway by acting as competitive inhibitors of the COX-2 enzyme. By doing this, NSAIDs reduce swelling, redness, and pain levels (RiccioTTI and FitzGerald 2011). In a study done by Oak et al. (2014) the effects of the anti-inflammatory drug, licofelone, on the repair of an injured rotator cuff were examined. The goal of this study was to determine if the presence of licofelone had a positive or negative effect on the ability of muscle fibers to produce force following repair. Any reductions in force production would be interpreted as problems relating to the repair of muscle fibers. This study examined the supraspinatus muscle of the rotator cuff of Spague-Dawley rats, which had been surgically torn using the deltoid-splitting technique and then repaired with Mason-Allen sutures (Figure 2) (Oak et al. 2014).

A 40 mg/kg dose of solid licofelone was dissolved in hydroxypropyl methylcellulose (HPMC) to make a liquid solution that could be administered to the rats via a stomach tube. The control rats were given HPMC without licofelone at the same rate as the experimental group. At the end of a 28 day recovery period, the torn and repaired muscles were removed from the rats and a combination of biological assays was performed in order to determine the role of NSAIDs in muscle repair (Oak et al. 2014).

The results showed no differences in muscle mass measured by gross anatomical examination. There was also no difference seen in the cross-sectional area (CSA) of the muscle samples. There was, however, a 36% size reduction seen in both type I and type IIA fibers present in the licofelone treated muscle. The number of type IIB fibers doubled in the drug-treated muscle, which accounted for the appearance of unchanged muscle mass, while the number of type IIX fibers decreased by half (Oak et al. 2014).

To test the contractility of the muscle, muscle fibers were isolated and placed in a solution to relax the fibers, which ultimately allows for a complete contraction. The muscle was then attached to a servomotor and a force transducer. The results of these contractility experiments showed no differences in the CSA. Maximum isometric force and specific force of the licofelone treated muscle displayed a significant decrease of 27% and 23%, respectively (Oak et al. 2014).

To analyze gene expression, messenger RNA was isolated from the muscle using a miRNeasy kit (Oak et al. 2014). Analysis of the adipogenesis and lipid storage transcripts showed no clear pattern with a significant decrease in PPAR-γ, perilipin 1, and FSP27 and a significant increase in DGAT1, perilipin 5, FIT1, ACAT. Inflammation and atrophy related genes showed an increase in COX-2, IL-10, embryonic myosin heavy chain (eMHC) but no increases any of the others in this group. The autophagy test showed significant increase in each of the genes measured: beclin-1, Vps34, ATG16L1, and ATG5. For the extracellular matrix synthesis and fibrosis markers, increases were seen in MMP8 and scleraxis (Oak et al. 2014). There were no significant differences seen in macrophages and fatty macrophage accumulation (Oak et al. 2014).

The content of hydroxyproline, an amino acid associated with collagen, was also examined. Hydroxyproline is often used as a biomarker for collagen in muscle tissue (Oak et al. 2014). The results showed that half the amount of hydroxyproline was present in the licofelone treated muscle, compared to that of the control muscle (Oak et al. 2014). Following the hydroxyproline assessment, triglyceride and phospholipid levels of the muscles were examined. The results showed a 78% reduction in the triglyceride levels in licofelone treated muscles while levels of phospholipids were similar in both samples (Oak et al. 2014).

The last part of the experiment performed by Oak et al. (2014) involved gross anatomical analysis and biomechanical testing. Anatomical testing of the enthesis of samples showed increased redness, inflammation, and size (Oak et al. 2014). Biomechanical testing was done using Electroforce ELF3200 uniaxial testing system with a 100 N load per cell, which is a standard load. For all biomechanical tests, the humerus with the supraspinous muscle still attached was used. The maximum load to yield, the peak stress, peak stiffness, and CSA data were obtained as well. The results showed that there was no difference in the tendon CSA of the muscle...
samples and no differences in the displacement to yield amount. There was a 62% increase in the maximum load, a 51% increase in peak stress, and 73% increase in the peak stiffness of the licofelone-treated muscle samples (Oak et al. 2014).

The authors concluded that when a non-selective COX inhibitor was present during muscle fiber regeneration, there was a stronger bone-tendon attachment, less inflammation, and stronger load to failure levels. This suggests that the use of NSAIDs can have a positive effect on the regeneration of muscle after injury.

COX Inhibitors Impair Healing in Rabbit Model
In a study done by Lu et al. (2015) the effects of both selective and non-selective COX inhibitors on the process of post-injury muscle regeneration in rabbits were studied. Ibuprofen and flurbiprofen axetil were used as non-selective COX inhibitors and celecoxib was used as a selective COX-2 inhibitor (Lu et al. 2015). The goal of this study was to determine the effects of the use of COX inhibitors on the repair of injured muscle tissue.

Ninety-six New Zealand white rabbits were used as the animal model for this study because of the anatomical similarity of the rabbit shoulder to the human shoulder (Lu et al., 2015) and the fact that shoulder injuries are among the top four injuries that occur along with hand, knee, and ankle injuries. The rabbits were divided into four groups and randomly assigned to one of three experimental COX inhibitor groups or the control group. The supraspinatus muscle was surgically torn using the deltoid splitting technique and repaired using Mason-Allen sutures (Figure 2) (Lu et al. 2015). The rabbits were given post-operative penicillin for three days to prevent infection. Following this precautionary step, NSAID treatments were begun (Lu et al. 2015).

For biomechanical testing, the supraspinatus muscle was dissected, isolated from other nearby muscles, and placed into the MTS-858 biomechanical testing system. The sample was loaded to a 2.5 N cell, which is a low load cell, and load to failure was tested at a speed of 1 mm/s (Lu et al. 2015). For this test, the maximum load at failure and percentage of maximum load were recorded. The results showed that the percentage of maximal load to failure decreased on the surgically repaired side of the muscle as compared to the normal side. After three weeks, there were significant differences between the celecoxib and flurbiprofen axetil groups and the control group. There was no difference seen between the ibuprofen and the control group. At week six, there was only a significant decrease seen in celecoxib group compared to the control group. Flurbiprofen and ibuprofen did not show any significant differences. The same results were observed at week twelve (Lu et al. 2015).

![Figure 2](https://example.com/figure2.png)

**Figure 2.** Surgical technique for tearing and repairing the Supraspinatus muscle (Ssp) in rabbits. The tendon of the Ssp was removed from the greater tubercle (GT) of the bone using the deltoid splitting technique (A) and (B). A Mason-Allen suture was used to close the wound (C) and biomechanical testing was done with the Ssp muscle loaded to a MTS-858 system (D). Infraspinatus (Isp) positioned and labeled. Adapted from Lu et al. 2015. Illustration by Kelly Paralis, Penumbra Design, Inc.

The ibuprofen group received 10 mg·kg⁻¹·d⁻¹ of ibuprofen in their normal food post-operatively for seven days (Lu et al. 2015). Flurbiprofen axetil, was administered intravenously to another group of rabbits for seven postoperative days at a dose level of 2 mg·kg⁻¹·d⁻¹ per day. The third group of rabbits received 8 mg·kg⁻¹·d⁻¹ of celecoxib in their food for seven post-operative days (Lu et al. 2015). After a recovery period, the rabbits were sacrificed and the muscles were removed. Of the twelve rabbits in each treatment group, eight were tested at each post-operative time point: three weeks, six weeks, and twelve weeks. Histological and biomechanical analyses were done on all sample muscles (Lu et al. 2015).

The Possible Effects of Non-steroidal Anti-inflammatory Drugs (NSAIDs) on the COX-2 Pathway of Skeletal Muscle Repair
Histological analysis was carried out in order to view the fibrovascular granulation, fibrocartilage formation, and presence of Sharpey's fibers and to quantify the amount of collagen at the bone to tendon attachment (Lu et al. 2015). The results of this study at three weeks indicated poor fibrovascular granulation tissue in all of the drug treatment groups. The ibuprofen and control groups showed little osteoclastic activity and cartilage formation. At six weeks, there was similar fibrocartilage formation and Sharpey's fibers were observed in ibuprofen, flurbiprofen axetil, and control groups but not the celecoxib group. At twelve weeks, there were hypercellular and fibroblastic cells present in ibuprofen, flurbiprofen axetil, and control groups. The celecoxib groups showed no cartilage and no new bone formation (Lu et al. 2015).

Quantification of collagen levels revealed that there was less collagen I in the celecoxib and flurbiprofen axetil groups compared to the control while there were no significant differences seen when ibuprofen groups were compared to the controls. At six weeks, there was less collagen I in the celecoxib than in the control groups, but there were no differences seen in ibuprofen and flurbiprofen axetil groups. The same results were seen at week twelve (Lu et al. 2015).

The Lu et al. (2015) study found that there were decreased levels of maximum load to failure in the mechanical testing phase. These results conflicted with the findings from Oak et al. (2014). This may be due to the fact that different NSAIDs were used in the studies. Licofelone, a non-selective COX inhibitor, showed an increase in muscle strength (Oak et al. 2014) while celecoxib, a selective COX-2 inhibitor, showed a decrease in muscle strength (Lu et al. 2015). These results may indicate the importance of the COX-2 pathway in the process of regenerating a functioning muscle and suggests that functional muscle may not be produced when the COX-2 pathway is inhibited. The results of Lu et al. (2015) also indicated that both selective and non-selective COX inhibitors impact the repair of muscle after injury. This conclusion was supported by both the histological and biomechanical analysis.

**Summary**
The studies done by Oak et al. (2014) and Lu et al. (2015), present conflicting results regarding the effects that COX-inhibiting anti-inflammatory drugs have on the process of muscle repair following injury. The Oak et al. study (2014) suggested that the non-selective inhibition of COX-2 leads to the production of muscle tissue that has less scar tissue and lipid accumulation, increased levels of maximum load to failure, and reduced levels of inflammation on both the gross anatomical and the cellular gene expression levels. These results indicate that the muscle is stronger after repair in the presence of NSAIDs. These results are very different from the results obtained by Lu et al. (2015) when a selective COX-2 inhibitor was used as an NSAID. The Lu et al. (2015) study showed that there was decreased muscle strength and detrimental structural differences in collagen and the enthesis in the presence of NSAIDs.

Interestingly, the negative effects of the inhibition of COX-2 on muscle tissue repair were supported by Shen et al. (2005) and Schoenfeld et al. (2012). Shen et al. (2005) reported fewer regenerating myofibers, more scar tissue accumulation, higher levels of transforming growth factor (TGF)-β1, and lower amounts of neutrophil and macrophages in muscle fibers treated with NSAIDs. They suggested that the lack of new muscle fibers after injury made room for scar tissue to accumulate over time. The high levels of TGF-β1 observed in this study are indicative of fibrosis and the presence of muscle tissue fibrosis is also supported by the increased amount of scar tissue. The study done by Shen et al. (2005) used the selective COX-2 inhibitor NS-398. The use of a different COX-2 inhibitor may be why these results differ from the findings of Oak et al. (2014), which found decreased amounts of scar tissue and increased numbers of fibers. Selective COX-2 inhibition strongly suggests that the COX-2 pathway is necessary for the proper repair of muscle fibers.

Additional results regarding the effects that inhibition of COX-2 pathway by a selective inhibitor are evident in a study completed by Schoenfeld et al. (2012) This study suggested that a reduced number of stem cells were activated in injured muscle tissue in the presence of NSAIDs. The study results held true when NASIDs were used over time. If NSAIDs lead to a decrease in the activation of myogenic stem cells over time, this could lead to the production of abnormal muscle tissue (Schoenfeld, 2012).
The effect of specific COX-2 inhibition on muscle repair was stronger than the effect of non-specific COX-1 inhibition (Lu et al. 2015, Oak et al. 2014, Shen et al. 2005, Schoenfeld 2012). The difference in the results between the inhibition of non-specific COX/LOX and specific COX-2 inhibition may have been due to the specific role that each pathway has on the regeneration of muscle. COX-1 is responsible for homeostatic responses such as maintaining the integrity of the gastrointestinal mucosa, mediating normal platelet function, regulating blood flow through the kidney and acute inflammation (Crofford 1997). COX-2 is pro-inflammatory and in animal models of inflammatory arthritis, COX-2 increases along with PG production and the progression of clinical inflammation. Increased COX-2 expression has been observed in models of endothelial cells, chondrocytes, osteoblasts, and macrophages in vitro following the introduction of proinflammatory cytokines, such as interleukin 1 (IL-1) and tumor necrosis factor-alpha (TNF-alpha). COX-2 is also increased in some types of human cancers, particularly colon cancer. (Crofford 1997). COX-1 is expressed continually, while COX-2 is expressed only when needed (Bondesen et al. 2004).

There are more side effects associated with the use of non-selective COX inhibitors (COX-1) because the enzymes are produced regularly (Ricciotti and FitzGerald 2011). There are fewer side effects associated with the use of selective COX inhibitors (COX-2), which is why they are prescribed for chronic use with patients struggling with rheumatoid and osteoarthritis (Ricciotti and FitzGerald 2011). Since non-selective COX inhibitors affect more than one pathway, the effects may not be as strong as direct inhibition by a selective NSAID. Non-selective COX inhibitors primarily inhibit the COX-1 isoform with only a slight inhibition of COX-2 (Bondesen et al. 2004). The slight inhibition of COX-2 allows for the production of some prostaglandins, which means the inflammation pathway will still be initiated. Selective COX-2 NSAIDs fully inhibit any prostaglandin production by the COX-2 isoform, which is what leads to the effects on the muscle regeneration (Bondesen et al. 2004). These differences in inhibition may account for the variation in the observed results for selective and non-selective COX inhibiting NSAIDs.

The overall effect of anti-inflammatory drugs on the COX-2 pathway of muscle regeneration remains unknown. More research is needed to fully understand the effects of the inhibition of the COX-2 pathway on muscle repair following injury. Future research should include studies that use commonly prescribed selective COX-2 NSAIDs, studies that examine the use of NSAIDs over extended periods of time, and studies that incorporate higher doses of NASIDs than are typically prescribed by physicians. These types of studies will help to more fully elucidate the effects of NSAIDs on the COX-2 pathway in the repair of skeletal muscle following injury.

Illustration courtesy of
Kelly Paralis, Owner
Penumbra Design, Inc.
143 North Sylvania Avenue, First Floor
Rockledge, PA 19064
Tel: 215-379-2832

About the authors
Megan Obarowski graduated from Arcadia University with a Bachelors of Arts in Biology in the spring of 2017. She is enrolled in an Accelerated Bachelors of Science in Nursing program at Gwynedd Mercy University for the fall of 2017. After completing the BSN program, she plans to continue her education in nursing to become a nurse practitioner.

Sarah Cooper is an Associate Professor of Biology at Arcadia University and Editor-in-Chief of the HAPS Educator. She has taught human anatomy and general biology at Arcadia University since 1981. She is the pre-nursing adviser and the coordinator of the interdisciplinary science courses at Arcadia and she has served as a member of the Arcadia University Judicial Board since 1984.

John Daley, PhD is an Assistant Professor of biology at Arcadia University where he serves as the coordinator of the Introductory Biology courses. He teaches Junior Seminar, General Biology I and II, and microbiology labs and is an active participant on departmental and university committees.

Randy Tammara is a pharmacist who has been working in the Philadelphia area for twenty-five years. He is a certified diabetes educator who gives presentations to care-givers through Northampton Community College, Bethlehem, PA where he is an adjunct faculty member in the Community Education Division. He is currently enrolled in the Masters in Public Health program at Arcadia University.

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continued on next page
The Possible Effects of Non-steroidal Anti-inflammatory Drugs (NSAIDs) on the COX-2 Pathway of Skeletal Muscle Repair


A Massive Open Online Course (MOOC) for Implementing Pedagogical Tools in Undergraduate Respiratory Physiology

Sophie Dandache, PhD1, Mariane Frenay, PhD1, Marie-Claire Van Nes, MD, MA, MBA2, and Franck Verschuren, MD, PhD3

1 Assistant Professor and post-doctoral researcher at the Psychological Sciences Research Institute of the Université Catholique de Louvain (UCL) in Louvain-la-Neuve, Belgium.
2 Medical Education Unit, Health Care Sciences, Université Catholique de Louvain, Brussels, Belgium
3 Department of Acute Medicine, Cliniques Universitaires Saint-Luc, Université Catholique de Louvain, Institute of Experimental and Clinical Research, Brussels, Belgium
Franck.verschuren@uclouvain.be Corresponding Author

Abstract

Massive Open Online Courses (MOOC) have received increasing attention in recent years for their potential to engage on-campus students in active learning while conveying knowledge to a broad international public. In this article, we describe the creation of a MOOC as a mandatory integrated supplement to a respiratory physiology and pathophysiology university course taught to undergraduate medical students. We discuss how this MOOC integrates several didactical tools such as flipped classroom activities, peer-review evaluations, active learning principles or multidisciplinary fundamental-clinical approaches. The impact and satisfaction analysis on 8,400 participants, including seven percent of medical students, suggests that a specific scientific subject from an undergraduate medical curriculum could stimulate the motivation of both on-campus and international students. This MOOC experience renews the view on medical education and deserves further development.

Key Words: MOOC, international education, medical education, undergraduate medical curriculum

Introduction

Advances in communication technology have triggered the development of online teaching since Professor Sidney Pressey created the first electronic learning device, the ‘Automatic Teacher’, in 1924. Since then, we have been observing a shift in the development of online education where the influence of change in education has replaced change in technology with a growing focus on soft skills and education (Adams and Morgan 2007). It is in this perspective that Siemens and Downes from the University of Manitoba created the first massive open online course (MOOC) in 2008. This MOOC had a decentralized non-linear structure based on networking and focused on exploration and conversation rather than on instructor-provided content (Mackness 2013). It was however, a few years later that MOOCs met their huge popularity with a course by Sebastian Thrun and Peter Norvig from the University of Stanford titled “Artificial Intelligence” that was taught in 2012. This new MOOC followed a more traditional teaching approach being hyper-centralized, content-based and linear. Today, MOOCs are typically focused around a set of short, modularized video-lectures, followed by different types of assignments, e.g. multiple choice questions, quizzes, etc.

Given the advantages of MOOCs and their use in education, it is surprising that medical schools have been slow to adopt them. Ninety-eight MOOCs related to health and medicine were offered in 2013 (Liyanagunawardena 2014). Although it is widely accepted that online learning is effective, the potential role of MOOCs in medical education remains under researched (Pickering 2017). Even the description of a medical MOOC design remains scarce (Murphy 2013, Reinders 2016, Swinnerton 2017).

That is why we decided in 2014 to create a MOOC format as a supplement to a medical course titled “Respiratory Physiology and Physiopathology”, which is taught to undergraduate students in the second year of medical school at the Université Catholique de Louvain (UCL, Belgium). The main objectives for this ambitious project, in addition to opening an international course, targeted the teachers of two groups of learners, students on campus and international students. For the international teacher and his/her university, the aim was to provide an innovative tool that would help to stimulate and reinforce student motivation. For the on-campus teacher and his/her students, the aim was to foster active learning by using the MOOC as a tool in a flipped-classroom. The MOOC was envisioned as an opportunity for international students to master human respiratory physiology (excerpt from the text of the video teaser: https://www.edx.org/course/respiration-human-body-louvainx-louv8x-1) while attending a university level course.

The aim of this article is to describe the steps that lead to the creation of a new MOOC in medical undergraduate education by focusing the reader’s attention on the pedagogical tools underlying its construction.

Method

Respiratory Physiology and Physiopathology is a course taught to undergraduate students of the second year of medical school at a large French-speaking University in Belgium. This course is offered every year to an average of 300 students and represents three credits out of a total of 60 credits needed to complete the medical school program.
The MOOC
The MOOC “Louv8x: Respiration in the Human Body” was created as an integrated complement to a Respiratory Physiology and Physiopathology course, rather than as a replacement for the course. It follows the structure of a traditional course in which the theoretical content is transmitted through videos followed by multiple-choice quizzes or other types of assignments. Clinical cases are used as a starting point to introduce the basic and fundamental pathophysiological concepts presented by the textbooks of West (West 2007) and Nunn (Lumb 2016) and by the clinical instructor’s experience. Louv8x contains five major sections:

1) the basics of breathing (atmosphere, anatomy, physics)
2) oxygen and carbon dioxide
3) daily breathing (sport, altitude, pregnancy, diving)
4) breathing and diseases (asthma, emphysema, pulmonary edema, pollutants, and smoking)
5) supplements for medical students on pulmonary compliance, surfactant and fibrosis.

Video capsules
Video capsules constitute the framework of the course content, as is typical for all MOOCs. The aim of these videos is to convey a large amount of information in an efficient way despite the relatively short length of the video. We therefore used two main sources of inspiration. The first source was Khan Academy, which is an educational organization created in 2006 by Salman Khan. This organization provides free lectures through short YouTube videos illustrating theories of various topics in a tablet drawing style. Supplementary exercises and tools for educators are provided. The second source was ‘C’est pas Sorcier’, a very popular French educational television program that produced 559 episodes between 1994 and 2014 on diverse topics such as history, biodiversity, physics or health. ‘C’est pas Sorcier’ provides theoretical explanations of scientific phenomena through field visits, miniature models, and lab experiments. By referring to these two educational designs, we aimed to capture and hold the student’s attention by conveying the information in different ways. Students are alternately presented with simple graphs and diagrams created with a drawing application. Interviews with experts are shown, and metaphorical representations such as an electric train to represent oxygen transportation, nylon stockings to represent lung compliance, and a bathtub to represent ventilation, are used throughout.

Discussion forums and quizzes
In addition to providing knowledge with videos, we proposed features for promoting student comprehension. Quizzes and questions follow each video and guide students in their learning and understanding. Inviting students to share their learning experience in the forums triggers cognitive and emotional engagement. It is worth noting that the educational team is not excluded from these interactions as they follow up on the forums and propose ‘hangouts’ sessions consisting of live ‘question and answer’ sessions.

Daily work
Each video capsule is followed by creative, concrete, and personal assignments the aim of which is to promote active learning. For instance, students can be invited to:

1) Apply knowledge they have acquired. For example, to ‘simulate hyperventilation’, the student is asked to lightly hyperventilate and write down the symptoms experienced and estimate the alveolar ventilation.
2) Analyze clinical data. For example, to ‘estimate the expiratory flow in asthma patients’, the student must calculate his theoretical peak flow using tables and compare it with imaginary pathological values.
3) Synthesize clinical information. For example, the student is asked to ‘choose a respiratory pollutant, and summarize its mechanism of action’.

Evaluation
When constructing the evaluation tools, our choices were guided by the desire to have tools that would not be only evaluative but also be formative. More precisely, for the evaluative part, students are invited to answer short assignments after almost every session. They are presented with multiple-choice quizzes and image-based exercises in which the student is asked to point to a certain part of the graph/image or enable annotation problems e.g. problems to which the answers are limited to a word on number.

Finally, a mid-term and a final exam were proposed consisting of open questions assessed by peers. More precisely, participants had to answer a few open-ended questions. A few days later participants received an evaluation grid for assessing two other participants as well as their own work. In sum, each paper is evaluated three times and the end score represents the mean of the three evaluations (Chen 2012, Speyer 2011). The peer evaluation technique is an opportunity to engage student involvement and responsibility. Students are encouraged to reflect on their work and contribute to the group. They are encouraged to develop their judgment skills and to provide relevant feedback (Bostock 2000, Karakitsiou 2012). In addition to their usefulness, the development of these skills is a requirement for our undergraduate students. Peer assessment is a very handy tool to help students acquire these competences.

Flipping the Classroom
One of the aims of creating this MOOC was to use it as an innovative tool to complement the on-campus course in a blended learning strategy known as a “flipped classroom”. Part of the instruction for a flipped classroom is delivered online outside the class while the educator guides students to apply the theoretical concepts and engage creatively in the subject during the classroom sessions. This type of
teaching is encouraged by education experts and contrasts with the traditional lecture where students passively receive information from the instructor (Prince 2014). In addition to being a positive experience for students, active learning methods also imply a change in the role of the instructor, who becomes rather a ‘guide on the side than a ‘sage on the stage’ (Stinson and Milter 1996).

Target audience
The MOOC “Louv8x: Respiration in the Human Body” was created as a supplement to a university course. Hence a sufficient level of complexity needed to be maintained so the MOOC could be used as a complementary tool to the classical ex-cathedra course. Louv8X must stay nonetheless accessible to everyone so no prerequisites are required from the on-line participants who wish to enroll. Despite the many advantages that a MOOC offers to online and international students, our priority remains our on-campus students and our MOOC needs to benefit them first.

Analysis
After enrolling in Louv8x, participants were invited to answer an online survey about their occupation, the reason why they enrolled in the course, and their degree of familiarity with the MOOC’s topic. At the end of the MOOC, participants were invited to answer a second survey related to their appreciation of the different aspects of Louv8x and their perceived competence before and after having taken the course. Students had to indicate on a ten-point Likert scale whether they disagreed or agreed with the statements. Degree of satisfaction was then reported on a four-point Likert scale that evaluated the following aspects of the course: workload, calendar, grading, quality of the videos and the quizzes, interactions, messages, hangouts, team presence, guidance and the technological environment.

A paired student t- test was used for comparing results before and after having followed the MOOC. A Mann-Whitney U test was conducted to compare the means of on-campus students and international students.

Results
The MOOC ‘Louv8x: Respiration in the Human Body’ was built during a six-month period preceding its first edition in 2015. Adapting the course into a MOOC required the mobilization of an educational team of approximately ten people (see acknowledgment section) that was involved throughout the whole creation process. The team was also involved in the course follow-up and the launch of each new edition. Third-year medical students managed the discussions on the MOOC forum and its translation into English.

Enrollment in Louv8X was as follows: 2,700 participants in 2015 and 5,700 in 2016 (51% in French and 49% in English), of whom 2,040 (24%) were considered as active and regular students. Medical students on campus represented approximately seven percent of the cohort.

The MOOC starts with an introductory video that offers an overview of the course content: https://www.edx.org/course/respiration-human-body-louvainx-louv8x-1

The course content is spread over eight weeks for a total of twenty videos of +/-10 minutes each. Figure 1 shows an example of a screenshot from a video made in the playful manner of the French “C’est pas sorcier” style. Figure 2 shows an example of Khan-style tablet drawing for explaining immunological aspects of asthma. We maintained a multidisciplinary approach with the videos with references to various disciplines such as histology, pharmacology or immunology. The link with these disciplines is particularly obvious in fifteen academic expert interviews inserted into the videos.
Each video session is followed by an evaluation of the student knowledge with short tests like multiple choice quizzes and image-based exercises (Figure 3). More complex learning tasks, demanding active learning, are then proposed in order to apply, to analyze, and to synthesize the knowledge. Answers to those tasks are posted on the discussion forum and eventually commented upon by the participants. This continuous evaluation constitutes the “daily work” category. The educational team also proposes two ‘hangouts’ sessions, the first one after 2 weeks and the second at the end of the course. The hangouts consist of live question and answer sessions broadcasted on YouTube: See the link: https://www.youtube.com/watch?v=NRvNCvHmLc0

A mid-term and a final exam are organized according to a peer-evaluation process. To obtain a certificate, both continuous assessment and final certification are taken into consideration for calculating the final grade. The certificate may be optional for international students. We made the peer evaluation task compulsory for the on-campus students. Extra points (five points out of a total of 20 in the first edition and two out of a total of 20 in the second) were added to the final ‘traditional’ university exam to those on-campus students who successfully followed the two peer evaluations certifications. We observed that 98% of them obtained the maximum grade. We consider the time for following one video and its evaluation to be approximately one hour. To allow some extra time for the students, we reduced the number of classroom sessions from 35 hours to 31. The classroom sessions are designed to discuss the theoretical material students viewed at home through interactive ‘flipped-classroom’ activities such as multiple-choice exercises with Wi-Fi or SMS interaction, respiratory experiences conducted in the classroom, and above all, by taking the time to explain the more difficult aspects of the course.

Due to the scientific orientation of the Louv8x MOOC, it is expected that the international students have (or are willing to acquire) basic knowledge of biology and human anatomy in order to understand the scientific terminology. In total, 90% of 506 international participants answering a ‘pre-MOOC’ survey had a type of professional or non-professional understanding of the topic. A substantial number of active participants in the discussion forum were professional respiratory physiotherapists. Seventy percent of the participants (N=350) had a profession and only two percent of participants were looking to acquire a certificate.

Table 1: Descriptive and mean comparisons on a scale going from 0 to 10 for competence, and 0 to 4 for satisfaction (going from ‘Not at all’ to ‘Very much’)

<table>
<thead>
<tr>
<th>COMPETENCE</th>
<th>Online participants (N=109)</th>
<th>On-campus Students (N=59)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluating</td>
<td>4.91 ± 1.18</td>
<td>5.24 ± 1.36</td>
</tr>
<tr>
<td></td>
<td>8.20 ± 1.40</td>
<td>8.60 ± 1.18</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.05</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Distinguishing</td>
<td>3.48 ± 3.08</td>
<td>3.74 ± 3.00</td>
</tr>
<tr>
<td></td>
<td>8.42 ± 1.16</td>
<td>8.04 ± 1.60</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.05</td>
<td>p &lt; 0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SATISFACTION</th>
<th>0 to 5</th>
<th>0 to 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.67, 58</td>
<td>3.19, 85</td>
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</tr>
<tr>
<td>3.69, 51</td>
<td>3.51, 65</td>
<td></td>
</tr>
<tr>
<td>3.65, 59</td>
<td>3.28, 82</td>
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<tr>
<td>3.64, 54</td>
<td>3.40, 69</td>
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<td>3.94, 23</td>
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<td>3.93, 25</td>
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<tr>
<td>3.64, 57</td>
<td>3.36, 72</td>
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<td>3.14, 83</td>
<td>2.73, 93</td>
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<tr>
<td>3.65, 54</td>
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<tr>
<td>3.32, 73</td>
<td>2.95, 89</td>
<td></td>
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<tr>
<td>2.03, 22</td>
<td>2.57, 32</td>
<td></td>
</tr>
<tr>
<td>2.79, 43</td>
<td>2.25, 48</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Descriptive and mean comparisons on a scale going from 0 to 10 for competence, and 0 to 4 for satisfaction (going from ‘Not at all’ to ‘Very much’)

The self-competence perception before and after the MOOC was significant and similar for both groups of students. Table 1 shows that the mean satisfaction for each group and each parameter were above average. International students were slightly more satisfied than the on-campus students. These differences were statistically significant (p <.05) for workload, grading, educational design, video, interactions, and team presence.

A Massive Open Online Course (MOOC) for Implementing Pedagogical Tools in Undergraduate Respiratory Physiology
Discussion

This paper described the creation of a MOOC as a supplemental tool for undergraduate medical students in which several instructional designs were employed while conveying medical knowledge to a broader public. In particular, we implemented didactical video capsules with a clinical context integrating fundamental and clinical information, peer- and self-evaluations, active learning principles, interactive discussions in forum, flipped classroom activities, and personal assignments. An improved perceived competence and satisfaction was confirmed both for on-campus students and international students, the latter declaring to be slightly more satisfied.

Cook et al. have previously pointed out that employing proven and context-appropriate principles of learning was more important in terms of learning efficiency than the modality, in this case online versus a traditional course presentation (Cook 2014). Our study confirms the feasibility of integrating several didactical tools into an undergraduate medical curriculum, those tools embracing student engagement and motivation. In this sense, we participated in the re-imagination of medical education, relying not so much on the technologies but on a pedagogical perspective about medical teaching and student learning (Doherty 2015, Prober 2013).

Criticisms and warnings have been published about the pedagogical value, the learning outcomes, and student time efficiency when using a MOOC (Daniel 2012, Hortsch 2015, Kirschner 2013). We therefore kept in mind throughout the creation and editing process that our priority in terms of course content and pedagogical goals remained our on-campus students. However, several factors might explain the slightly lower general satisfaction for the MOOC by on-campus students in comparison with international students. The general context for an undergraduate medical student involves a higher rate of constraints in terms of requirements for a successful examination. The integration of two didactical supports (ex-cathedra and online), the insertion of the MOOC amongst the general workload of second-year medical school courses, and the mandatory regular MOOC study throughout the semester instead of just before the exam session, may have been perceived as unnecessarily burdensome by some of the on-campus students.

Amongst the several challenges, dealing with two different student populations was critical. The international online students were far more numerous than the on-campus students, ninety-three percent versus seven percent. The population of on-campus students had a mandatory need to pass a university exam for a high-level university course. Dealing with two populations of different interests has been previously shown to potentially disrupt traditional teaching practices (Ng’ambi 2015). The rare on-campus student participation in the discussion forum or hangout sessions, the lack of interaction between on-campus and international students, the lower rate of peer-evaluation participation for the international students, all confirmed different behaviors between both populations.

The certificate value of the MOOC among on-campus students has been a subject of discussion: 5 points out of a total of 20 points for the first edition and 2 points out of a total of 20 for the second edition. There are currently no complete credits for university students following a MOOC and there is no guarantee of authenticity through the physical presence of supervisors during the examination (Doherty 2015). Factoring in the MOOC for part of the final certification mark seemed to us a compromise in valuing the weight of the MOOC in the final grade for on-campus students.

Finally, a major drawback we have noted in the creation of the MOOC is the financial and time investment that it requires. Previous articles have shown that benefits of online learning come at a price (Cook 2014). Considering those issues, while we do recommend trying the ‘MOOC experience’, it is important to consider at first the goals that one wants to reach in order to evaluate whether the cost-benefit ratio is satisfactory.

The main limitation to the MOOC concerns the low number of on-campus students participating in the surveys, limiting the weight of their contribution in the discussion. Our primary objective was to describe a new MOOC creation while considering its various pedagogical tools.

Conclusion

Creating Louv8X was a very satisfying experience and helped us to renew our view on education. The first editions proved that a very specific scientific subject in an undergraduate medical curriculum, such as respiratory physiology and pathophysiology, could stimulate the motivation and the satisfaction of both on-campus and international students. Using this tool in a context of a flipped classroom allowed us to increase our interactions with the on-campus students. Using a peer-assessment tool helped us to provide students with skills they need to acquire at the end of their study program. Using video capsules allowed us to integrate a multidisciplinary approach to a clinical context. Using personal assignments and interactive discussions allowed us to encourage active learning. We however want to stress that, although enriching on many levels, the efficiency of education and the pedagogy of medical learning were not improved by the MOOC itself, but rather by the way several pedagogical tools were included and tested throughout this MOOC. Given the costs in terms of time and money to develop a MOOC, we believe that the numerous pedagogical tools we have explored need to be further developed in medical education.
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About the Authors
Sophie Dandache, PhD is Assistant Professor and postdoctoral researcher at the Psychological Sciences Research Institute of the Université Catholique de Louvain (UCL) in Louvain-la-Neuve, Belgium. She obtained her master degree in Psychology in 2009. She recently started a postdoc as a member of the MoocQuality program at UCL

Mariane Frenay, PhD is full Professor at the Faculty of Psychology and Education of the Université Catholique de Louvain (UCL) in Louvain-la-Neuve, Belgium. She is a researcher at the Psychological Sciences Research Institute of the UCL. She was Dean of the Faculty of Psychology and Education between 2009 and 2015.

Marie-Claire Van Nes, MD, MA, MBA, Certif Med Educ is a specialist in geriatric medicine with an interest in medical education. Her topics of interest are clinical reasoning and work-based assessment of medical trainees.

Franck Verschuren, MD, PhD is a Clinical Professor in medicine at the Université Catholique de Louvain (UCL) in Brussels, Belgium. He teaches respiratory physiology and pathophysiology, and acute medicine. He is head of clinic in the emergency department of the Cliniques Universitaires Saint-Luc in Brussels.

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A Method for Maximizing Dissection Experience with a Minimal Number of Cadavers in an Undergraduate Human Gross Anatomy Laboratory Course

Catherine E. Mattinson, PhD1 and Elisa M. Konieczko, PhD2

1Gannon University, Zurn 211, 109 University Square, Erie, PA 16541
2Gannon University, Zurn 203, 109 University Square, Erie, PA 16541
konieczk001@gannon.edu, mattinso001@gannon.edu

Abstract
Many schools offering undergraduate human gross anatomy (HGA) laboratory courses with cadavers teach these courses in one of two formats: either as a lab in which students review structures from prosected cadavers or as a lab in which three to six students fully dissect a cadaver during the course. This article presents an approach that hybridizes these two formats to provide students with cadaver dissection experience that does not overwhelm their class schedule. In our single semester HGA laboratory course students learn from one prosected cadaver while each lab section of 20 students dissects their own cadaver. Each student dissects for 90 minutes per week: 30 minutes of dissection time during their scheduled lab and two required 30 minute dissection homework labs. The experiential aspect of performing these dissections invests and engages students in the course material and helps students to understand anatomical relationships. Undergraduate teaching assistants make this approach possible. doi: 10.21692/haps.2017.014

Key Words: prosected cadavers. student dissection, lab procedure, undergraduate cadaver dissection, cadaver laboratory

Introduction
In institutions that have a cadaveric component to their undergraduate human gross anatomy laboratory courses, the courses are typically taught in one of two ways (Dinsmore et al. 1999). In one method, students use prosected cadavers to learn human anatomy. This way is advantageous in that it potentially allows multiple semesters of students to learn from the same cadaver, thus reducing the number of cadavers needed to successfully run a course. Because the prosected cadaver is dissected ahead of time, students can begin learning structures immediately, without having to work to dissect the structures for themselves. Additionally, since prosections are usually performed by advanced students or instructors, the quality of the dissection is superior to that of many first-time anatomy students. However, there are limitations to learning anatomy solely through prosection. The repeated handling of human tissue, no matter how carefully it is done, eventually leads to damage and loss of the integrity of the structures. Some studies have shown that there is no difference in exam scores between students who learn from prosected specimen and those who are engaged in dissection (Ashdown et al. 2013, Nnnodeim et al. 1996), while other studies have shown that there is an educational benefit for students who do the dissection themselves (Johnson 2002, Marshak et al. 2015). Students who dissect also have the opportunity to develop a variety of skills that may be important for a career in health care (Ellis 2001, Granger 2004, Rizzolo 2002).

In a second method, undergraduate human gross anatomy labs are taught in a manner similar to that of graduate professional programs. These courses typically have smaller enrollments and only three to six students are responsible for dissecting a cadaver in its entirety during the semester. Students in these courses gain dissection experience comparable to that of first year medical students, which is especially valuable for pre-professional undergraduate students. However, because of the amount of work required to accomplish these dissections, students must make a time-intensive commitment to this type of course. Additionally, sophomore and junior level students often struggle with the study pace of anatomy (Elizondo-Omana et al. 2006). The financial cost of such a course is also substantial since a greater number of cadavers are necessary to accommodate the small groups of students.

In an effort to obtain the positive impact of prosection and dissection without extensive time or financial commitments, Gannon University offers a hybridized course that allows undergraduate students to learn from a prosected cadaver as well as gain dissection experience. In this approach, multiple scheduled lab periods are not required for students to complete their dissection. This article explains how the Gannon University Human Gross Anatomy Laboratory (BIOL 366) course uses both a prosected cadaver and student-dissected cadavers to teach anatomy and test our students. Our rotational system of dissection during scheduled lab
periods, as well as our dissection homework labs, allow our students to average 90 minutes of dissection experience per student, per week, while keeping the number of cadavers needed to run our course to a minimum. In order for a system like ours to work, teaching assistants (TAs) are needed to supervise dissection homework labs.

Course Description and Background
Gannon University currently offers multiple sections of an undergraduate Human Gross Anatomy lecture course (BIOL 365) and a co-requisite Human Gross Anatomy laboratory course (BIOL 366) during the fall and spring semesters. Typically, 80 students enroll in the two courses in the fall semester, and 60 students enroll in the courses during the spring semester. Each of the lecture sections is capped at 40 students, and each of the lab sections is capped at 20 students. The lecture course (BIOL 365) consists of three 55-minute lectures per week, and the laboratory course (BIOL 366) is one three-hour lab period per week, with required dissection homework labs outside of the scheduled lab period (see Dissection Homework Labs and Supplemental Instruction below). Pre-requisites for these courses are two introductory biology courses with their associated labs.

Human Gross Anatomy and its lab are required courses for sophomore students in the Gannon University five-year physician assistant program and for junior pre-physical therapy students. These courses are also strongly recommended for upper level pre-professional students including those who are planning to matriculate to medical or dental schools.

Lab Period Procedures
Each lab section of 20 students is assigned one cadaver that they are responsible for fully dissecting over the course of the semester. Since there is only one lab section scheduled per day, each cadaver is referred to by the day of the week associated with its lab section. The dissection of these cadavers occurs during the scheduled lab period as well as during our dissection homework labs. In addition to one cadaver per lab section, we also have one cadaver that is dissected by our TAs one week prior to the start of each new topic. This cadaver serves as our prosected cadaver for all of the official lab sections during the semester.

The Human Gross Anatomy lecture and lab courses follow a regional approach to teaching anatomy. The course is divided into four sections that cover thorax and abdomen, head and neck, back and upper extremity, and pelvis and lower extremity. At the beginning of each of these sections, the 20 students within each lab section are randomly assigned to groups of three to four students, for a total of five to six small groups. Changing the groups with each section of material accomplishes goals including allowing the students to meet and work with a variety of their peers and encouraging students to foster inter-professional relationships by working with other students outside of their specific major. Since each group is together for 3 to 4 weeks, the differences that may arise among group members over student study habits and preparation are more easily tolerated. Additionally, this system allows all students to have an opportunity to work together avoiding the cliques that often form when students self-select the members of their group.

Most lab periods begin with a short lecture that pertains to the material to be dissected that day, for example, the layers of the rectus sheath or the boundaries and contents of the femoral triangle. After the instructor has lectured and covered the learning objectives for the week, the student groups are each assigned to a station. Each of the cadaver tanks is a station and we also have a station that consists of bones, x-rays or CT scans displayed on light boxes, and organs from our soft tissue collection (Figure 1), (Kang et al. 2012). Student groups remain at each station for approximately 25 minutes before their group is rotated to the next station (Marshak et al. 2015). When the students are at the station of another group, or at the prosected cadaver station, they are responsible for identifying structures that have been dissected over the course of the previous week and reviewing material. Students are encouraged to use their atlases and a basic “words to know” list in their dissector to identify structures on their own and to consult with the instructor or TA if they have a question or need clarification.

Figure 1. The layout of our lab and the order in which students rotate through stations during their scheduled lab periods is shown. Student groups rotate through stations including a station that consists of bones, X-rays, CT scans, and MRI films displayed on a light box, and organs from our soft tissue collection, as well as our cadaver tanks (prosected cadaver (P), Monday lab section cadaver (M), Tuesday lab section cadaver (T)), Wednesday lab section cadaver (W), Thursday lab section cadaver (Th)).

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When students are stationed at their cadaver, they dissect. Typically, one student in the group acts as a “reader” while the other students in the group are dissecting. The reader’s job is to follow the dissection instructions in the dissector, inform the students performing the dissection of what they should be doing, find appropriate pages in atlases for the students to reference when they’re trying to locate a structure, and take note of anything important, for example, abnormalities/variations in structures, to pass along to the next group of students that will dissect. The job of the reader rotates every lab period among the students in the group so that everyone has a chance to dissect over the course of a section of material.

Teaching Assistants
TAs are necessary for the lab course to run as described in this article. Teaching assistantships at Gannon University are paid positions through work study programs, and each TA may work up to 10 hours per week. TAs are recruited from students who have earned at least a “B” in both BIOL 365 and 366, and who have shown themselves to have good dissection skills and excellent interpersonal communication skills. Many students are eager to work as TAs because they know that the opportunity will be a unique experience to list on professional or graduate school applications, or when applying for jobs. We typically have five TAs during the fall semester and four TAs during the spring semester.

TAs are responsible for dissecting the procured cadaver one week ahead of the material covered in lab. The dissection is done at the TAs convenience, and the instructors and TAs meet for one hour every Friday to review the dissection for the upcoming week. This gives the instructors the chance to review all of the anatomy with the TAs, and well as make sure the dissection is complete prior to the first scheduled lab period on Monday.

Other TA tasks include setting up the lab prior to scheduled lab periods and cleaning up the lab following these lab periods. TAs assist the instructor with answering questions during the lab period and TAs host dissection homework labs and supplemental instruction labs, termed open labs. TAs also help with practical exam set up, proctoring, and exam grading.

Dissection Homework Labs and Supplemental Instruction
Students are required to complete two 30-minute dissection homework labs per week for points in the course. Homework labs are in addition to regularly scheduled lab periods. The TAs pick two times per week (usually in the late afternoon or evening hours but also on the weekends) to host a block of two 30-minute dissection homework labs followed by a one hour open lab. The schedule of these labs is created the first week of class and remains constant throughout the semester.

The homework lab schedule is made available to students on our course management site.

For each scheduled lab period, there are four dissection spots available in each dissection homework lab. Thus, if you are in the scheduled lab section that meets on Monday, you only ever dissect on the Monday cadaver and you can only sign-up for one of the four spots available for Monday students in a given dissection homework lab (Figure 2). This system keeps the number of students dissecting at any one time on each cadaver to a reasonable and safe number. It also ensures that the TAs have time to work with each group and answer questions during dissection.

Figure 2. An example of our dissection homework lab sign-up sheet demonstrates the four slots available for students from each scheduled lab period to sign-up for a dissection homework lab. The title at the top of the sheet indicates that this is the first dissection homework lab on a Tuesday and it is from 4:00 to 4:30 pm. At the time of sign-ups, students write their name in the first box and then sign when they come in to perform the dissection so that we have a record of the student’s presence.

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Spots in dissection homework labs and open labs are available on a first come, first serve basis. The sign-up sheets are put out in a binder every Monday at noon outside of the lab. In the event a student cannot make the sign-up time, another student may sign-up for them. Students sign-up by printing their names on the dissection homework lab sheet for a specific lab. When the students actually show up to do the dissection they sign their names so that there is proof of their attendance.

The TAs also offer supplemental instruction via open labs, which are essentially study halls with the cadavers. Open labs are not required but they are strongly recommended for students who want to do well in the course. Open labs are capped at 40 students each and sign-ups for the open labs occur at the same time as the sign-ups for the dissection homework labs (Figure 3). Students may attend up to five open labs per week. During the open lab periods students usually sort themselves into groups and then the TA uses a rotation system to ensure that each group has an equal amount of time at each station.

**Figure 3.** The open lab sign-up sheet has 40 spaces available for students to attend a one-hour open lab. The title at the top indicates that this is the first open lab on a Monday and it is from 6:30 to 7:30 pm. Because open labs are not mandatory we do not require students to sign in when they arrive for an open lab.

**Testing and Grading**

In BIOL 366, approximately ten percent of the grade comes from dissection homework labs. The remaining 90% of the grade is equally divided among four lab practical exams. Each lab practical exam consists of 40 question stations, each with two questions, for a total of 80 points (Figure 4). Question stations may consist of tags on the cadavers, organs from the soft tissue collection, scan or X-rays, bones, or anatomical models. There are five rest stations interspersed throughout the exam and three bonus question stations at the end of the exam for a total of 48 stations. Students are given 75 seconds at each station before they are rotated to the next station. Students may not go back to any stations at a later time (Zhang et al. 2013).

**Figure 4.** The first page of our blank exam form provides space for two answers (a and b) at each numbered station.

Given the amount of time it takes to set up the practical exam and the amount of information that needs to be covered in this course it is not possible to sacrifice an entire week to testing and it is not practical to repeatedly set up the exam. Thus, the first three exams are scheduled on Saturdays and the fourth exam takes place on a designated day during finals week. Exams are graded by the instructors and TAs immediately following the practical.

Obviously, there are issues that arise with Saturday lab practicals. In the event that a student cannot make an exam...
for a prior personal commitment or another university event occurring on the same day, we offer an oral makeup exam the following week. However, this policy has now been in place long enough that most students know that Saturday exams three times during the course of the semester are to be expected.

There are several benefits associated with Saturday lab practicals. With all of the students from all of the sections taking the exam at the same time on the same day, there is not an opportunity for students to share exam content with others who have not taken the exam yet, thus maintaining the integrity of the exam. Students who require additional time for exams due to learning disabilities or medical conditions take the exam on Saturdays as well after the majority of the class has taken the timed exam. One instructor remains in the room to answer questions and supervise the students.

Conclusion
The undergraduate human gross anatomy laboratory course offered at Gannon University takes the features of both prosection and student dissection cadaver lab experiences and combines them into one course that gives students exposure to anatomy and dissection techniques while keeping costs down and using fewer cadavers. This provides our students with a hands-on opportunity to learn the human body, which leads to investment in mastering the material and a sense of pride in the work that they complete. Additionally, dissecting allows our students to understand important three-dimensional relationships among structures, as well as topics like fascial planes, variant blood supplies, and metastatic disease (Zhang 2016).

This system works well for us because a culture has been created over many years that supports the requirements and rigor of this course. Paid TAs, supplemental instruction, and Saturday exams are part of what makes this method of teaching a cadaver anatomy lab run smoothly at our university. However, the authors acknowledge that resources like these may be difficult to initially obtain or implement at another institution. In the end we believe that our method results in a compromise that gives our students the advantages of both prosection and dissection in an anatomy education.

About the Authors
Catherine E. Mattinson PhD is a former Assistant Professor at Gannon University where she taught undergraduate human gross anatomy courses to pre-health professions students and human anatomy and physiology courses to allied health professions students. She is a member of the HAPS Cadaver Use Committee. She recently relocated to Ohio with her family.

Elisa M. Konieczko PhD is a Professor at Gannon University. She is a member of the American Association of Anatomists and the American Association for Cell Biology. She primarily teaches undergraduate human gross anatomy courses, but she has also taught cell biology lecture and lab courses.

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Bringing Escape Room Concepts to Pathophysiology Case Studies

S. Richelle Monaghan, PhD\textsuperscript{1} and Scott Nicholson, PhD\textsuperscript{2}
\textsuperscript{1}Departments of Health Studies and Biology, Wilfrid Laurier University, 73 George Street, Brantford, ON N3T 2Y3
\textsuperscript{2}Game Design and Development Program, Wilfrid Laurier University, 73 George Street, Brantford, ON N3T 2Y3
rmonaghan@wlu.ca, scott.nicholson@wlu.ca

Abstract

Escape rooms are physical games set in fictional settings where participants work together to find hidden objects, complete tasks, and solve puzzles to escape the room in a limited amount of time. Escape rooms are problem-based, collaborative, and require interaction with physical aspects of the game. Portable escape boxes are games developed using escape room concepts but can be taken into the classroom. Instead of escaping a room, students work together to complete tasks to get deeper into the escape box. The examination of pathophysiology case studies is well suited for the use of escape boxes since they are inherently problem-based. Using escape boxes is a natural progression to further problem and team-based learning in the use of case studies in pathophysiology and medical education. This article explores the development of an escape box, presents the challenges and narrative of the game and discusses the lessons learned during the process. doi: 10.21692/haps.2017.015

Key Words: pathophysiology, medical education, escape rooms, active learning, PBL

Introduction

Escape rooms are “live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal, usually escaping from the room, in a limited amount of time” (Nicholson 2015). If participants are successful they escape the game and win the challenge. Escape rooms are collaborative, problem-based, time-constrained and active, which are often things that educators want to create in their classroom to promote learning (Bergman et al. 2013, Freeman et al. 2014, Schmidt et al. 2011). Escape games put participants in direct contact with each other and require them to collaborate in the physical world instead of having each participant lost in their own screen; therefore, they are excellent activities to enhance an in-person classroom setting.

Breakout EDU (www.breakoutedu.com) is an independent company that has popularized the use of escape room concepts in education by developing an open source platform for portable “escape boxes”, which are self-contained games based upon escape room concepts designed to be taken into the classroom. Instead of trying to get out of a locked room, the players are trying to get into a locked box. The Breakout EDU platform specifies types of locks and other basic hardware that educators can purchase. Educators can print information from the website or create locked access escape boxes. The Breakout EDU website contains hundreds of games that instructors have created for the platform and uploaded for other educators to use.

Using this Breakout EDU inspired method, an escape box was created for a third-year undergraduate pathophysiology course. The study of pathophysiology is well suited for the use of escape boxes. It is inherently problem-based as it requires learners to integrate their foundational knowledge from prerequisite courses, such as anatomy and physiology, to develop logical potential diagnoses and ideally an accurate final diagnosis. A standard teaching method to assist with the study of pathophysiology and this integration of knowledge is the use of case studies in the form of problem-based learning (PBL) and team-based learning (TBL) (McInerney and Fink 2003, Rendas et al. 2006, Vogeltanz-Holm et al. 2014). Case studies provide students with initial and sometimes intentionally incomplete information about a patient’s signs and symptoms, and students are required to actively inquire and investigate to gain information to develop their potential and final diagnoses. Using escape boxes is a natural progression to further PBL and TBL in the use of case studies in pathophysiology and medical education.

In this article, a pathophysiology case study escape box challenge developed for a small (20 students) third-year undergraduate course is fully described. To provide context to the depth of learning objectives for this activity, students in this course are in a combined Bachelor or Arts and Science program in Public Health. They have taken pre-requisite courses including human anatomy and physiology, infection and immunity, cell and molecular biology, and genetics. These students are positioned to apply to post-graduate clinical education. This article will outline the components, props and delivery of a pathophysiology escape box that was designed for a sepsis/septicemia case study. A debriefing of the escape box at the completion of the challenge is an important part of the learning process and is reviewed. In the Discussion section of this article considerations regarding
the escape box narrative, recommendations for escape box development, and potential challenges to accommodate larger class sizes, are outlined with the goal of assisting other educators, particularly in pathophysiology or medical education, with escape box development.

Escape Box Components and Parts
The educator/designer of an escape box challenge determines what component parts of the box are required depending on the case study and fictional narrative. Normally, the majority of component parts can be reused in the development of different escape box challenges allowing for extended use of the supplies purchased. While Breakout EDU is a specific platform for teachers to share games, the concepts behind the escape box can be used by anyone to create a live-action classroom game. However, generally it includes a box that can be locked with any variety of locks; a hasp typically used for electrical lockout boxes can hold multiple locks (Figure 1). Locks can be number combinations, lettered word combinations, keyed, or directional. All types of locks can be used in a challenge or the lock type can be limited to only a few types. The role of the lock in the escape box is to provide feedback to the learners; if the learners are correct, the lock will open, if they are wrong, they will know immediately that they need to try again. This immediate physical feedback is one of the powerful aspects of an escape box that makes them engaging for a classroom setting.

Escape box kits can be purchased from Breakout EDU or the educator/designer can improvise and build or purchase boxes to suit (Figure 2). For the pathophysiology escape box, the majority of the components were purchased at local hardware, office and medical supply stores. With a class size of 20 students, four identical escape boxes were developed for this challenge. The components of one pathophysiology escape box are listed below:

1. Toolbox (46 x 26 x 26 cm); designed to accept a separately purchased lock
2. 5-letter word combination lock
3. Clipboard with paper
4. Lockable zippered vinyl envelope
5. 3-number combination travel lock
6. Small box (16 x 9 x 11 cm) with lockable latch (key required)
7. One pair of nitrile gloves
8. One urine sample container containing approximately 30 mL of apple cider vinegar
9. Medium lockable box (22 x 15 x 10 cm); designed to accept separately purchased locks
10. Two 4-letter combination locks
11. Large Plastic envelope containing 5 sheets of paper
12. Small zippered purse
13. A variety of items that could be found in a purse: cell phone, gum, condom, lip balm, coffee card, loose change, matches/lighter, but must include a syringe (with needle removed for safety) and elastic headband or small tourniquet

Figure 1. A hasp, (indicated with a black arrow), holding a variety of locks on an escape box.

Figure 2. A single lock escape box used in the pathophysiology case study.
**Scenario Overview**

The narrative of the pathophysiology escape box has students work in teams as Emergency Room resident physicians. As they work their way through the narrative and scenarios, the students encounter props including triage information, lab results, patient samples, and the personal affects of the patient to enhance the experience and engage with the case study on a physical level. They read scenarios at each stage of the escape box to gain information they can use to solve problems related to the case study or to assist them with the integration of their knowledge. The goal for students is to work as a team to solve problems and provide an accurate tentative diagnosis and treatment plan for the fictional patient. If this goal is achieved, there are a few remaining challenges for them to consider regarding the treatment plan and care of their patient.

**The Escape Box Challenge**

Escape boxes are rolled into the classroom on a gurney, and the instructor enters in character as an emergency room physician wearing scrubs. Students are welcomed and informed that they have one hour to “Escape the Morbidity and Mortality (M and M) Meeting.” It is explained that in a hospital when a physician loses a patient, physicians are required to attend an M and M meeting to discuss individual and systemic issues that may have contributed to the loss of the patient. The goal of an M and M meeting is to try to minimize future preventable patient losses. To be successful at the escape box challenge and “Escape the Morbidity and Mortality Meeting” students are informed that in one hour they must accurately assess and treat their fictional patient, and follow the scenarios and challenges in order to do so.

The first scenario is read to them:

> You are an Emergency Physician Resident at Wilfrid Laurier Hospital in Brantford. It is Saturday night. It feels as though your shift just began, but you have already evaluated 3 patients with influenza (it is the season), one patient experiencing a severe asthma attack, one suspected myocardial infarction (they are currently getting a ECG), a likely concussion, a ring avulsion injury, and a parade of hematomas and lacerations.

> There has been a brief lull in triage and your Emergency Resident Supervisor, Dr. Monaghan, has suggested you take a break because you have a long shift still ahead. In the break room you grab a coffee and find a few colleagues working on a crossword puzzle. While you and your colleagues do not typically do crossword puzzles, this crossword is called “Considerations in Emergency Triage and Health History”. What the heck... for a laugh, you and your colleagues know this will be a breeze for you and work together on solving the puzzle.

> There are no more than 5 of you in the break room at a time... please work in groups of 5 or fewer.

Students are each given a sheet of paper with a crossword. The purpose of the scenario and crossword puzzle (Appendix A) is to initiate students to the scenario, have them establish their team members, and begin working as a team. While this short introduction is primarily to initiate teams and set up the narrative, fundamental terminology is reviewed and students are intentionally passively primed to concepts that they may consider during the escape box challenge.

Instructions on the page with the crossword are as follows:

> “You and your colleagues in the break room work on the crossword together (no more than 5 to a group). When you are finished, you return to work, but your supervisor questions that you have taken a break – you have a long shift ahead. Once one person in your group shows Dr. Monaghan (your residency supervisor) the completed crossword. It will be viewed as evidence of your break. You will then be given access to your next patient file.

**Crossword: Across**

1. Oral 36.8°C, Internal 37°C, and fluctuates
6. Think about it: A giraffe requires this to be 3 times greater than in humans
7. ‘Lub-Dub’: tachycardia, bradycardia
8. calor, dolor, rubor, tumor, and function laesa
9. This occurs at the cellular level to produce ATP, or at the systemic level to ventilate
12. How many voyages around the sun?
13. Has this happened before?
14. Undesirable reactions produced by a normal immune system

**Crossword: Down**

2. Marijuana, cocaine, MDMA, alcohol, tobacco
3. A bag or container’s past
4. Invasion of body tissues by an organism, their disease causing agents and the reaction of the host
5. Anti-depressants, codeine, Ventolin, Tylenol
10. ‘Under the knife’?
11. M, F, or U/X

As a member of each group provides evidence of their completed crossword puzzle, the instructor provides each group with a copy of the following scenario. Additionally, the instructor on their completed crossword circles the word “BLOOD” in “BLOOD PRESSURE”. The team member/student is told that the circled word is their Triage Password, and to read the scenario on the page provided and follow the instructions.
**SCENARIO:**

*Given to each team after they prove they have taken a break (by showing their completed crossword)*

While you were on break, a 25-year-old woman named Caitlin Fraser is brought into ER triage by several of her friends. They said they were out partying until Caitlin was complaining too much about feeling ill. Her friends thought she looked flushed but they were drinking, it was hot in the bar, and they dragged her onto the dance floor at least a few times. It was completely out of character for Caitlin not to be interested in going out on a Saturday night, but she said she hadn’t been feeling well for several days. They decided to Uber home, but changed their minds and made a pit stop at the hospital’s Emergency Department to drop Caitlin off.

The friends left once Caitlin was triaged. You can now access her Triage Information by entering in the Triage Password you were given by your Residency Supervisor.

*(Use the Triage Password to open the lock on the box.)*

**Please note: All characters in this active learning experience are fictional**

Students use their Triage Password (BLOOD) to open the 5-letter word lock on their escape box and gain access to its contents (Figure 3). Once inside the box students can see:

1. One clipboard containing “Confidential Triage Information of a fictional patient
2. One small locked black box
3. One zippered and travel padlocked envelope labeled “Confidential Lab Results”
4. One double-padlocked case with the letter “S” on its lid
5. One large plastic envelope labeled “Do not open until instructed to.”

The clipboard containing “Confidential Triage Information” of a fictional patient is the only readily available information. All other contents are locked or labeled not to open until instructed to. The triage information page is designed as a prop to look official on the clipboard. For effect, the university logo was modified to say “hospital” instead of “university” (see Appendix B). On the same page and below the triage information, the scenario is further described:

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**SCENARIO:**

You do not know what is making Caitlin feel unwell, but recognize she is exhibiting signs and symptoms that could indicate a minor illness that would resolve on its own, or various serious conditions that would require medical intervention.

You request that Caitlin provide a urine sample. She says that even though the last time she urinated was about 4 hours ago, she does not have anything to void.

You explain to Caitlin that you need to do some blood test in order to gain a better understanding of what might be going on. She agrees and allows for a blood sample to be taken. It is difficult to find a vein, and you notice that she had some unusual venipuncture sites. You inquire and she mentioned that she was not feeling well earlier in the week and her family physician ordered blood work as well. The nurse had a hard time finding a vein so she was “poked” several times before the nurse was successful at getting the sample.

You order a CBC (Complete Blood Count), Electrolyte tests, Lactic Acid Test, and Blood Culture.

At the bottom of the triage page after the scenario, there are instructions to turn the page over. On the reverse side of the page, instructions encourage students to use their internet access to research information on standard ranges and averages of vital signs if they do not recall them from their physiology pre-requisite course. Access to information using technology is a common practice in medicine and is realistic and appropriate for this learning activity. An empty table is provided for students to enter standard ranges to compare
with the patient’s triage information (see Appendix B and Appendix C). What they should notice from this comparison is that the patient’s vitals show an elevated temperature, heart rate, and possibly respiratory rate, and a low blood pressure. They may also question the moderate murmur noted at the lower left sternal border (LLSB), but there is no way at this time to determine if the murmur is important in the case, or an artifact. The patient’s triage values are designed to be not too extreme that the pathology in the case study is immediately revealed or that the patient is so ill that she dies before students have a chance to think about what is causing her distress. At this point conditions that could cause these altered vitals are extensive and range in severity potentially causing outcomes from discomfort to death.

Further information is provided below the chart students are given to compare standard ranges with the patient’s triage vital signs. This information is intended to guide and assist the students at their knowledge level to take the information they are familiar with, such as anaerobic glycolysis, and apply that knowledge to testing they may not have previously been aware existed. The information provided was as follows:

*Along with the CBC and blood culture, you ordered a Lactic Acid Test. Review the role of glycolysis and lactic acid in the anaerobic production of ATP. Why would someone have higher lactic acid levels?*

*To obtain the access code for Confidential Lab Results in the zippered pouch, correctly fill in the blanks with numbers. In glycolysis, 1 glucose molecule produces a TOTAL of ___ ATP. To produce this ATP it actually uses ___ ATP, resulting in a NET of ___ ATP.*

**The code can be entered into the lock by looking at the SIDE of the lock where there are number windows to arrange your code.**

The remaining exercises on the page have students reflect on glycolysis and the production of lactic acid in anaerobic conditions. This reflection is intended to inspire students to consider the causes of lactic acid production and anaerobic conditions before they receive more information. When students fill in the blanks on the activity regarding glycolysis, it provides them with the number “422” which is then used to obtain access to the zippered and locked pouch in the escape box.

Unlocking the envelope, students find a file folder prop (Figure 4), containing the Complete Blood Count (CBC) results for the patient (see Appendix D) and an additional piece of paper with the following scenario:

**Please find the Lab Report Enclosed with this Paper**

**SCENARIO:**

*Caitlin determines she is able to at least try to provide a urine specimen and heads off to the washroom with her urine sample collection pack. Before she returns you receive her blood work results.*

*Caitlin returns from the washroom and indicates that she is feeling much worse. In fact, she said she almost collapsed in the washroom. Caitlin reports feeling cold, is shivering, but is flushed on her face and extremities. You take her temperature and her fever has increased to 38.7 °C. She also seems out of breath from walking back from the washroom. A new symptom of shortness of breath has presented itself, and her rate of respiration is 24 breaths per minute. Her heart rate has increased to 100 bpm.*

*While you will not have her blood culture back for at least a few days, you recognize this patient is potentially experiencing a very serious medical situation and you consider calling the intensive care unit to discuss her case. First you take your suspicions to your Residency Supervisor.*

**Figure 4.** Within the “Confidential Lab Results” zippered and padlocked envelope, is a file folder prop containing the patient’s CBC lab results, and a piece of paper with more of the narrative (See Appendix D for lab results).
CHALLENGE:

Consider Caitlin’s case and her progression. It is true, there are no conclusive answers yet, but you are confident that if your team does not act fast, there will be a dramatic decrease in Caitlin’s platelet count, and a potentially fatal progression of her condition. What does the pathogenesis suggest she is experiencing? Talk with your team and write your answer in the space provided.

Have one person from your team approach your Residency Supervisor with your team’s diagnosis, and first priority treatment suggestion. Why would you suggest this tentative diagnosis and treatment suggestion?

TENTATIVE DIAGNOSIS:
FIRST TX SUGGESTION:
and WHY?:

**Please note: All characters in this active learning experience are fictional.**

Students are required at this point to integrate their pathophysiology learning objectives from the course, and knowledge from their pre-requisites, in order consider possible diagnoses. They are asked to develop a tentative diagnosis because the information they have been provided, while realistic to how a patient may present, is initially intended to be ambiguous enough to ponder several possibilities. In reality, the information students acquire by the time they need to make a tentative diagnosis and treatment plan is not enough information for a health care provider to be definitive about a diagnosis. Just as in health care, and with the condition of sepsis, evidence-based action must sometimes be taken before suspicions are confirmed through blood culture or other testing.

Students work in their teams to provide the instructor with their tentative diagnosis, first treatment suggestion, and justification for the tentative diagnosis and treatment suggestion. It is expected that students provide “sepsis/septicemia” as their tentative diagnosis, “broad-spectrum antibiotics/antibiotics” as a first treatment suggestion, and list the points that lead them to this diagnosis and treatment. If student teams develop an incorrect tentative diagnosis, such as respiratory alkalosis, pulmonary embolism or myocardial infarction (which are a few conditions, for example, that could present with an increased respiratory rate) there can be an acknowledgment of where their tentative diagnosis aligns with the signs and symptoms of the patient. Students may highlight other signs and symptoms and provide any number of diagnoses. It is at this point the instructor has an opportunity to see why students were thinking of an incorrect tentative diagnosis, support any correct thinking, and gauge how much the team requires redirection. Once students present their instructor with the correct tentative diagnosis, the instructor, while in character, hands the team a key. There is only one place where a key will work, which is in a small latched black box (Figures 3 and 5).

Using the key, students open the box to find a message, and props (Figure 5). The message states:

**Congratulations. You have successfully determined what Caitlin is suffering from. Please observe the contents of this box, and open the white envelope at the bottom of the main escape box, which is labeled, “DO NOT OPEN UNTIL INSTRUCTED TO.**

**Figure 5.** The contents of the small latched box. The box contains a pair of nitrile gloves, and a urine sample container with warmed apple cider vinegar to represent the patient’s urine sample. It is intended to be dark to indicate high solute concentration, and fluid conservation mechanisms of the kidney.

Inside the latched box is a pair of nitrile gloves and a urine sample container containing approximately 30 mL of apple cider vinegar to appear as concentrated urine. The non-biological “urine” samples had been warmed in the microwave prior to the escape box challenge to add realism and reflect the temperature from a recent urine sample. In the envelope there are five identical sheets of paper, one for each team member and the following instructions:

**Consider the urine sample that was collected. What are important observations regarding this sample? Implications of this sample should make you consider the Renin-Angiotensin-Aldosterone System.**

**Having determined that your patient needs to be in ICU with broad-spectrum antibiotics to treat what seems to be sepsis/septicemia you recognize that she will also need to be put on IV-fluids and vasoconstrictors such as norepinephrine and vasopressin. In discussing Caitlin’s case with your team members, you realize that not everyone is on the same page;***

continued on next page
perhaps they’re just tired from the long shift, but it could be they are not as familiar with the Renin-Angiotensin-Aldosterone System as they should be. You mention this to your Residency Supervisor as part of your risk management training. Your Supervisor tells each one of your team members to create their own RAAS flow chart or mind map to peer mentor each other.

Create a Mind Map or Flow Chart of the Renin-Angiotensin-Aldosterone System in the space provided. What aspects of your mind map/flow chart are influenced by administering IV-fluids and vasoconstrictors to your patient? This should take about 10 minutes. Then turn your paper over.

Students have previous experience with creating mind maps and flow charts in pathophysiology, and specifically in communicating Renin-Angiotensin-Aldosterone System (RAAS). They are at a point in their learning that they should be able to logically work their way through RAAS, describe why there is such a small volume of concentrated urine, and how the treatment of IV-fluid and vasoconstrictors impact RAAS. Before the escape box activity, students are not expected to anticipate the IV-fluid and vasoconstrictor treatment, but once offered the information they should be able to provide justification as to why this treatment would benefit the patient because of their knowledge of RAAS. After the escape box exercise, it is anticipated that students can generate an expanded understanding of sepsis treatment beyond the use of antibiotics, to include IV-fluids and vasoconstrictors.

On the other side of the paper it states:

Please do the activity on the other side of this paper first.

Take 10 minutes to complete the task on the other side of the page before returning to work on this side.

To discover the code for the lock on the Left Side of the Yellow Box (with handle facing you) (Figure 3), fill in your correct answer to the question below. Then use the numbers to determine the order of letters in the combination for the lock. On the lock, letters should line up along the red line.

To discover the code for the lock on the Right Side of the Yellow Box (with handle facing you), consider procoagulant and anticoagulant properties of blood. What condition can occur due to sepsis that essentially has both thrombotic and hemorrhagic properties occurring simultaneously throughout the cardiovascular system?

HINT: If your treatment plan for Caitlin hadn’t begun to help, she may have progressed to being bleeding from her venipuncture sites and gums.

Take your answer (3 letters), and add the letter on the top of the yellow box as the fourth letter in the combination lock. On the lock the letters should line up along the red line. (The letter “S” is on the top of the box.)

The combination locks open with RAAS, and DICS, respectively. With access to the last container in the escape box, students open the box and discover a small empty purse, and collection of items. The items include lip balm, a coffee loyalty card, eye drops, matches, a cell phone, condom, loose change, gum, and a syringe with tourniquet (Figure 6). The needle of the syringe is removed for safety. Inside the lid of the box students read the message:

Figure 6. The contents of the double-padlocked box. Once opening the box, these items are concealed by a small purse. This image represents what a participant can see once the purse has been removed.

Caitlin is now in ICU and you see that her personal belongings were not sent with her. As you pick up her unzipped purse to have sent to ICU, her belongings fall out. While putting everything back in the purse, a nurse informs you of the toxicology results from the urine sample Caitlin provided. Her urine came back positive for opioids. This is not as much of a surprise as it would have been had you not just seen the contents of her purse. Speculate on the possible cause of the sepsis.

Ending the escape box challenge with students becoming accidental voyeurs of the patient’s purse has more entertainment value than learning value. However, the props invite discussion during the escape box debriefing regarding potential causes of sepsis.

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Escape Box Debriefing
Once the escape box challenge is complete, an escape box debriefing enhances the educational value of the activity and is an important part of the learning process. It is a way for students to reflect, share, expand and connect more deeply with learning aspect of the escape box. Planned questions guide the debriefing and invite spontaneous discussion. Students can also take away the planned questions for further reflection, review and study.

During the debriefing, the learning objectives of the escape box challenge can be highlighted. For Public Health students in this pathophysiology course this includes their knowledge in health sciences but also learning objectives concerning social determinants of health. Students are informed of the reason sepsis was selected as this escape box challenge. Sepsis affects millions of people annually worldwide and, whether as individuals or as future clinicians, knowledge regarding sepsis can save lives. In Canada, sepsis was an underlying cause or contributing cause of one in 18 deaths in 2011 and contributed to the majority of deaths from infectious disease during the years 2009 to 2011 (Navaneelan et al. 2016). In the United States, the Center for Disease Control (CDC) reports that, based on death certificate data during 1999 to 2014, 6 per cent of all deaths were sepsis-related (Epstein et al. 2016). It is also relevant to discuss the challenges in reliable data collection on sepsis-related mortality because of several factors including surveillance definitions and the absence of confirmatory tests.

After a brief background on the relevance of using sepsis for the case study, students are invited to reflect and share their thoughts about their initial or retrospective evaluation of the patient’s confidential triage information. The following were planned questions regarding the triage component of the activity:

1. Reviewing the triage information, are there any points that stand out more prominently in retrospect?
2. What were your first impressions of the patient? Do you have judgment or biases about the patient’s behavior, gender or triage information that may have impacted her health care had this been a real scenario? If so, reflect on what and why that may be the case, and challenge your biases to see another perspective.
3. What about the heart murmur? Could it be related or is it an artifact?
4. What about the venipuncture sites? What are reasons patients may chose not to tell the truth? Do patient’s deserve quality health care if they are not truthful with their health care provider? Challenge yourself to see greater societal beliefs and potential consequences for this patient had she been truthful form the start about her intravenous drug use. Would you have taken her illness as seriously? Would you have made different assumptions about the venipuncture sites in triage had she been male? In reflecting on this topic consider other potential biases and try challenging them.

Reviewing the triage information students are encouraged to think of possible conditions or situations that could generate the signs and symptoms the patient presented with in triage, and the pathogenesis of these signs and symptoms in relations to sepsis (Table 1). Specifically what conditions could contribute individually to fever, elevated heart and respiratory rates, and low blood pressure? In relation to sepsis how do these signs and symptoms develop? With students’ background knowledge taken into consideration, it is expected that they begin to consider what signs and symptoms heart failure, pneumonia or other infections, sepsis, toxins, or co-occurring conditions could present for a patient. While the “LLSB heart murmur” is part of the patient’s triage information, it is not anticipated that students automatically know the short hand for Lower Left Sternal Border, or that endocarditis caused by bacterial infection could cause valve damage, a heart murmur, and spread to cause sepsis. This is a point that can be discussed during debriefing. Students have already studied bacterial toxins and their effects on the immune system in their biology pre-requisites, and have extensively studied the condition of sepsis in their pathophysiology course before they are introduced to the escape box challenge.

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During debriefing of the CBC lab results, students are guided through the results and reminded of learning expectations they should have already accomplished in order to speculate about the patient’s CBC values. The following were prepared questions and points to highlight for students:

1. The results indicate values to be outside standard ranges with high white blood cells (WBC), platelets, and lactic acid levels. What are common causes of leukocytosis, thrombocytosis and elevated lactic acid levels?
2. Review the role of inflammation, infection and leukemia in leukocytosis.
3. Review the role of platelets, platelet formation, and coagulation.
4. Review local and systemic conditions that can cause ischemia or hypoxia (such as pulmonary insufficiency, cardiac insufficiency, shock, toxins, embolism, aneurysm, DIC). What initially occurs at the cellular level during ischemia to continue ATP production?
5. What occurs at the cellular if ATP production is insufficient? Review how insufficient ATP influences reactive oxygen species (ROS), membrane integrity, protein folding, intracellular calcium, necrosis and apoptosis.
6. Review the role of lactic acid production in anaerobic glycolysis.

### Table 1. Case study presentation with commonly associated conditions and pathogenesis related to sepsis

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Commonly Associated Conditions</th>
<th>Pathogenesis Related to Sepsis</th>
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<tbody>
<tr>
<td>Fever</td>
<td>infection, neoplasia, conditions that cause inflammation, side effects of medication or recreational drugs</td>
<td>Bacterial toxins such as LPS from gram-negative bacteria act as pyrogens and also stimulate leukocytes to produce endogenous pyrogens. Pyrogens act on the hypothalamus, which is the thermoregulatory center. Fever can also increase heart and respiratory rates.</td>
</tr>
<tr>
<td>Elevated Heart Rate</td>
<td>physical exertion, low or high blood pressure, side effects of medications or recreational drugs, stress, heart failure, electrolyte imbalance, hyperthyroidism</td>
<td>Heart rate and contractility increase with an increase in sympathetic tone to the SA node and a decrease in vagal tone. Hypotension inhibits activation of baroreceptors (such as in the carotid sinuses and aortic arch), which increases sympathetic tone, as a compensatory homeostatic mechanism to maintain or normalize blood pressure.</td>
</tr>
<tr>
<td>Low Blood Pressure</td>
<td>reduced blood volume, heart failure, sepsis, medication, dehydration, anemia, anaphylaxis</td>
<td>In response to bacterial infection, immune cells release an array of cytokines (including the aforementioned pyrogens). These cytokines are both pro- and anti-inflammatory but some are more prominent in the development of sepsis (Chaudhry et al. 2013). Pro-inflammatory cytokines dilate blood vessels, which results in reduced vascular peripheral resistance and a decrease in blood pressure. Insufficient blood flow initially results in lactic acid production as a result of anaerobic glycolysis for the production of ATP. If ATP levels become insufficient, cell death and organ failure occur as a result. Pro-inflammatory cytokines are also linked to the release of tissue factor. Tissue factor promotes micro-thromboses formation in disseminated intravascular coagulation (DIC) and disrupts fibrinolysis (Vervloet et al. 1998).</td>
</tr>
<tr>
<td>Elevated Respiratory Rate</td>
<td>respiratory alkalosis, diabetic ketoacidosis, heart failure, anxiety, sepsis, pneumonia (infection), cystic fibrosis, pregnancy, heat stroke</td>
<td>Increased respiration occurs in response to stimulation of central and peripheral chemoreceptors that influence medullary and pontine respiratory centers. Fever, low blood pressure and changes in tissue gas pressures are factors related to sepsis that simulate chemoreceptors related to respiration. Increased respiratory rates can also be a result of damage to lung epithelium by the pro-inflammatory cytokines resulting in Acute Respiratory Distress Syndrome (Kim and Hong 2016).</td>
</tr>
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Considering the third-year undergraduate, non-clinical level of the students their understanding of CBC blood work is expected to be relatively superficial. However, they are familiar with the physiology, cell biology and pathophysiology associated with the elevated values found in the fictional patient’s blood work. The activity allows student to see how their knowledge is applied to blood work even though they are not expected to be familiar with lab results. A few specific points need to be made regarding platelet values. These high platelet levels were to indicate an acute-phase response prior to DIC. Platelet levels would be expected to drop dramatically as DIC progresses, as platelets would be recruited in developing micro-thromboses. If the escape box challenge lab results had provided low enough platelet levels to indicate progressed DIC, it would be unlikely that students would be able to save their fictional patient even with the correct diagnosis. Therefore in the design of the escape box, the decision was made to include an acute-phase response despite being beyond the knowledge level of the students. Students are, however, expected to associate platelets with procoagulation and clotting, and the activation of blood coagulation pathways as part of DIC.

The progression of sepsis and discussion of DIC allows for the opportunity to review the condition as a thrombohemorrhagic condition with clotting impairing circulation in the microvasculature, and the paradoxical bleeding that occurs. It is a serious and often fatal complication of sepsis, but discussion can be expanded to include other risk factors for DIC other than sepsis such as blood transfusion reactions, complications in pregnancy, and some leukemias. The platelet levels discussed from the patient’s blood work invite discussion regarding the pathogenesis of sepsis, DIC, and how patients will not always present in textbook fashion depending on the progression stage of the condition.

If you want to highlight a few other conditions the blood work reveals, it could be pointed out that the patient’s hemoglobin count, while well within standard range, would be considered high for a woman of childbearing age but doesn’t register for outside of standard values. It is her high hematocrit level that could falsely elevate her hemoglobin values.

After establishing the correct tentative diagnosis, students are led to review the Renin-Angiotensin-Aldosterone System (RAAS). They have extensively studied RAAS and its implication on blood pressure, blood volume, cardiac contractility, and renal function. From this exercise, it is anticipated that students easily review RAAS, learn that IV-fluid and vasoconstrictors are common treatments for sepsis, and be able to generate a logical justification as to why these are often required treatments for sepsis.

Lastly, debriefing ends with a discussion of the patient’s purse contents and the potential causes of sepsis. While this case study was intended to reflect bacterial septicemia potentially caused by contaminated syringes, more common causes of sepsis are pneumonia, urinary tract infections, and abdominal infections such as from appendicitis. Sepsis can be caused by other pathogens and the incidence in sepsis caused by fungal infections is rapidly increasing (Martin 2012).

Discussion
There are several considerations, recommendations and potential challenges to deliberate in the development of a pathophysiology case study into an escape box.

Consideration: The Role of the Narrative
While the physical aspects of the escape boxes are one way that this activity is different from a traditional in-class activity, another key difference is the role of narrative. In escape games, the players are placed in the middle of a story and have a key role that drives that story forward. Well-designed escape games are consistent in their use of narrative, so that every puzzle and item used in the game makes sense in the narrative. Having a consistent narrative conveyed through environmental storytelling helps the players to immerse themselves more fully in the activity (Nicholson 2016).

For a learning environment, the narrative provides something that can get lost in a classroom setting; context. The players can be placed in a role of someone needing to use the information in a setting that simulates something from the real world. The challenges in the game can then either be used before the learners work on a topic area to get them more interested and help them understand why something matters, or after the learners have explored a topic area to reinforce and contextualize learning.

It is through a consistent narrative that the designer brings together a set of tasks, engages the players, and provides this context. Without a narrative, the puzzles will feel shallow to the players, and the novelty of opening a lock instead of getting a mark will wear off quickly. In a well-designed educational escape game, the puzzles and locks should be tools used to create a player experience that helps them to better understand content. The narrative is just as important as the physical components and challenges in creating a good player experience.

In pathophysiology case studies, the narrative can begin to be built around items that occurred naturally in the case study. These could be items that are found in the environment of someone unconscious, the electrocardiogram (ECG) from a stress test, or perhaps the mechanism of injury such as a framing nail from a nail gun. The narrative for the case study first requires creative storytelling to expand from the patient’s clinical presentation. In many ways, the development of the narrative is the development of the fictional person associated with the clinical picture, and can play an important additional role in recognizing social factors related to health.
From the story, what are physical items or props that could be used for students to physically interact with? Humanity, humor and intrigue can be woven into the case study with props to enhance student interest, and in meeting course learning objectives.

**Consideration: Flow and Complexity**
A key building block theory for game design is the concept of Flow. The theory of Flow is based upon the idea of making a game more challenging as the player gets better. Keeping the player in the state of Flow will keep them engaged and interested in the game. If the game is too complex too quickly, players will be frustrated; if the game does not get more difficult as the players get better, players will be bored (Csikszentmihályi 1990). In the case presented here, the players are first given a low-stakes, narrative-light crossword puzzle. Once they have solved this, they are then ready for the more complex challenges to come. This also allows the team to form so that they are ready to perform as the game continues.

The “Escape the Morbidity and Mortality Meeting” challenge was a relatively linear challenge. Students could consider several conditions but as additional information was provided in scenarios, it was expected that they correctly arrive at the tentative diagnosis. The expectations and amount of flexibility to inquire were appropriate for the students’ level of knowledge. If an escape box is being designed for clinicians, a less linear scenario could be designed with potential plot twists, and more significant consequence to error. Options can include dead ends where participants need to back track to reevaluate where they made an error, or fail states where the players can lose the game from choosing incorrectly.

A way to begin development of this type of escape box is to evaluate the learning objectives and identify actions that the clinical learners need to know not to do. From there, in an escape box challenge, if they choose that potentially dangerous option for the patient they enter a dead end scenario as described. Another scenario could be that if the clinical learner selects a dangerous option for a fictional patient (such as selecting the incorrect drug concentration or treatment on a labeled envelope) they may have to meet with their fictional “supervisor” and spend 5 minutes outlining why that option was inappropriate before continuing on the escape box challenge. Creativity is an important key to developing escape boxes and establishing what is to be learned during the activity.

**Recommendation: Playtesting and Feedback**
Once an escape box is developed and the narrative, props and challenges are in place, it is important to playtest the activity with willing test subjects. On the first playtest there will inevitably be aspects of the challenge that can be flagged for improving clarity, guidance or the narrative. For example, one question raised during the development of this game was: if there is paper in the escape box that has information or activities on both sides of the page, is it important that participants do or read one side first? If so, this needs to be clearly communicated, and numbering the page may not be enough. In the pathophysiology escape box challenge described, this was accomplished by indicating at the bottom of the first page that they should turn the paper over, and at the top of the second page stating, “Please do the activity on the other side of this paper first”. Another way to deal with this problem would have been to use envelopes with instructions on the front and back that said “Do not open until instructed” (although excited players may open them anyway). A third method is to put different stages of the challenge in different locked containers so that players can’t access activities ahead of time.

When playtesting, it is important to ensure that at least some of the playtesters have not had experience with these types of games. Using experienced playtesters can be useful at the beginning of the playtesting process, but as the game is improved, it is important to bring in testers who are more representative of the target players. This is important for exploring the difficulty level of the game; most new designers
make their games too difficult or include too many challenges on their first pass and have to cut things out to make the game fit within the allotted time.

By observing playtests and incorporating feedback, many or all of the major issues of how the activity will flow for participants will come to light. Once modifications are made from the playtest feedback, it is time to launch the challenge in the classroom setting. Despite the effort and attention to detail that have been invested in the development of the escape box to this point, there may still be little challenges that arise. For example, clear descriptions of where the code for a combination lock lines up are important to include. It can be frustrating for participants if they have the correct answer, figure out the correct combination, but then enter the combination in a way that does not open the lock. To reduce frustration, specific instructions can be included, such as “On the lock, letters should line up along the red line” or a lock demonstration can be given before the game is started to ensure everyone knows how to use the locks in the game. Without playtesting, the game will most likely fail in one or many ways when it is launched in the classroom.

**Potential Challenge: Class Size**

One of the challenges an educator faces is how to deal with large classrooms. The box as it stands only supports about six people around it. One route is to purchase multiple boxes and give each group a complete set of all of the content, props, and boxes, although this can be cost and space prohibitive. Another solution is to have smaller boxes, each for a different challenge, scattered around the room at stations, and the teams work on paper challenges at a table, then when they have a solution, they can try the solution on a lock at a station. They then re-lock the lock for the next group. A third route is to have a ticketing system with a single guess, where teams fill out a ticket with their guess, bring it up to the single box at the front, and stand in a queue to try the lock. The reality is that the locks are simply a way to check an answer and the instructor could look at the answer and tell the team they are right, but that would take away the excitement a learner gets when their skills and knowledge had a small physical impact on the world by opening the lock.

In a larger pathophysiology class, there could be several case studies and teams could be working as departments, such as triage, radiology, and laboratory. This type of escape box challenge could infuse a dynamic of collaboration among teams, urgency, and priority, which are all realistic elements in health care.

**Post-Mortem and Conclusion**

A post-mortem is an activity commonly practiced in game design where the developers of the game look back at the game after its completion and talk about what worked well, where there were problems, and ways to improve the game experience. In the “Escape the Morbidity and Mortality” challenge, there were several aspects of the game that went well. Many of the challenges aligned with learning objectives or goals regarding the pathology of sepsis and the activity highlighted to students the growth they had experienced as learners. Specifically, students recognized that the complexity of the game would have been beyond their knowledge and ability in previous years, and while they were successful at completing the activity, the challenge was also difficult enough for them to feel accomplished at its completion.

Another success of the escape box was the general excitement that it elicited with a narrative accompanying the case study. During debriefing, pathophysiology was extensively reviewed, but it was clear that students were invested in the fictional character of Caitlin as their patient. Discussion and reflection on the social determinants of health was generated beyond what was typically discussed in the class case study reviews prior to the escape box activity. It appeared that the experience reinvigorated student motivations for taking the course, and for some, their future goals as clinicians. As well, the novelty of interacting with the physical boxes, locks and props created a unique experience that was memorable and stimulated an excitement to work together as their fictional emergency room team. Lastly, the flow of the escape box for participants was straightforward and without incident. This was due to the extensive playtesting that was conducted, which caught many issues that would have otherwise caused confusion. Overall, and anecdotally, the pathophysiology escape box was a success with highlighting student learning, reinvigorating motivation, and creating a memorable experience using novelty.

While there were several successes with the escape box activity, particularly around the support of pathophysiology course learning objectives, from a game design perspective, there are several areas where the narrative and sense of immersion could be improved to potentially enhance the immersion and learning experience. A logistical improvement could be to have teams selected randomly or pre-selected by the instructor. The outcome of students selecting their own teams resulted in students grouping themselves with their peers, which also seemed to align with their academic performance in the course; students doing well in the course grouped with others doing well in the course. All teams were able to accomplish the task, but there were significant differences in academic strength and problem-solving skills among the teams.

Another way this game could be improved is to apply Nicholson’s “Ask Why” model (2016) to each step of the narrative to improve the consistency of the world and increase immersion. For example, why does a word taken from five letters of a crossword puzzle open a locked box that contains information about a patient? Who set that lock, and what relationship did they have with the puzzle? If the
patient was just brought into the hospital during the break, then how did the information about this patient get put into a locked box so quickly? If the “why” question is asked during the time of design, then the design can be changed to create a consistent narrative; it can be difficult when the “why” question is asked later to re-think the underlying structure of the game.

Continuing the “Ask Why”, why would the numbers related to three different aspects of ATP be used to lock a pouch? Instead of using an artificial combination of numbers, using something that is a more standard method of combining or reporting numbers from the field would be more natural. Moving on to the next challenge, the players report to the supervisor, who hands them a key. What does that key represent in the game world? What would be locked up that would require a key? In this case, the container could represent the lab, and the players are opening the lab to get at the samples or finding the locked storage in the lab.

When there is a chance to add an additional physical space to the experience, it can help with immersion. In this case, the small box could be placed in another marked area of the classroom, with one envelope per team labeled “Take one envelope and relock the box”, so the players could be directed to go into the “lab” and search for the locked storage, with instructions to lock it up once done. This concept of getting players more physically engaged with the game by changing the space is based in environmental storytelling, where elements from the environment convey the narrative.

The next step of the game has the players use diagnostic codes to unlock a box and get Caitlin’s effects. Again, applying “Ask Why” concept here leaves a narrative gap to be filled. Why is it that knowing that DIC is a serious complication of sepsis allows access to the personal effects of Caitlin? One way to develop this would be to have Caitlin’s purse in another part of the classroom, and have the players get instructions in the box they unlock with the diagnosis that progresses the narrative, telling the players they have successfully diagnosed Caitlin’s condition, that she has been moved to ICU, and that the players should go to storage and get Caitlin’s belongings. Once they get a purse (which will need to be replaced by the instructor after each team), there will be a card attached to it that moves the story along. This also would be an opportunity to use a video instead of a physical purse, showing hands grabbing and dropping the purse, having items spill out for the players to see, and then the players are given the continuation of the challenges.

Cooperative live-action games bring players together in a physical space, which increases engagement and opportunities to learn from peers. Physical simulations have been a cornerstone in the health training fields, but these can be cost-prohibitive to set up. Escape boxes allow for a lower-cost classroom activity that can use simulation and game design concepts to bring groups of students together and create an intense exploration or review of course content. Creating an escape game is challenging, and as the reader can see is never complete as there are always ways to improve the game. If the game is used every semester, then a second in-class activity can be to ask the students who played the game to then help redevelop the game for the next year; not only can this reinforce the learning, but will serve to give the instructor a chance to learn from their students.

About the Authors
Richelle Monaghan, PhD (Biology), is professor at Wilfrid Laurier University in Brantford, Ontario Canada, where she is the Head of Science Programming in Public Health. Her primary teaching role is in undergraduate human anatomy, physiology, and pathophysiology. Recently, she received the inaugural Gail Jenkins Teaching and Mentorship Award from HAPS.

Scott Nicholson is a professor of Game Design and Development at Wilfrid Laurier University. He makes games to change the world through the Brantford Games Network and BGNlab (http://bgnlab.ca). He is a published game designer and is focused on tabletop games, escape rooms, game-based learning and meaningful gamification.

Acknowledgements
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Disclosure
The authors are not affiliated with Breakout EDU, which is an independent company run by former classroom educators.

Literature cited


Appendix A. Crossword puzzle used in the initial escape box challenge, generated with Crossword Puzzle Generator at TheTeachersCorner.net.
Appendix B. Confidential Triage Information found on the clipboard inside the escape box.

CONFIDENTIAL
WILFRID LAURIER HOSPITAL PATIENT TRIAGE INFORMATION

PATIENT NAME: CAITLIN FRASER
D.O.B: AUGUST 1, 1991
AGE: 25
SEX: Female

COMPLAINT: Feeling unwell, feeling hot/fevered, weak, tired. Flushed on face and extremities
TRIAGE HR: 82 BPM; moderate murmur noted at the LLSE, patient unaware of murmur history
TRIAGE TEM: 38 °C
TRIAGE BP: 100/63 mmHg
TRIAGE RR: 18/min
TRIAGE SaO2: 96%

MEDICATIONS: none, occasionally takes MV

NOTES: Has been feeling unwell over the past week, but progressively felt worse this evening. She has consumed 3 alcoholic drinks this evening.

Appendix C. Students are encouraged to compare and reflect on the patient’s triage values and standard ranges and averages.

CONFIDENTIAL
WILFRID LAURIER HOSPITAL PATIENT TRIAGE INFORMATION

What is the normal standard range, and average for oral temperature, heart rate, blood pressure and respiration? Using Caitlin’s Emergency Triage information, evaluate if any of Caitlin’s signs appear to be of concern. Do age or sex play a role in these norms? Use your internet access to determine these norms if you do not know.

<table>
<thead>
<tr>
<th></th>
<th>Standard Range &amp; Average</th>
<th>Caitlin’s Triage Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral Temperature</td>
<td></td>
<td></td>
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<tr>
<td>Heart Rate</td>
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<td></td>
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<tr>
<td>Blood pressure</td>
<td></td>
<td></td>
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<tr>
<td>Respiratory Rate</td>
<td></td>
<td></td>
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</tbody>
</table>
Appendix D. The lab results are expected to encourage students to think about why there may be elevated WBCs, platelets and lactic acid values in the patient’s blood work.

![CBC Lab Results](image)

Appendix E. The answer “Increase Blood Pressure” is added to the spaces. The numbers correspond to letters and the order of the letters for the lock combination. The code is “RAAS”.

What is the PRIMARY role of the Renin-Angiotensin-Aldosterone System?

<p>| | | |</p>
<table>
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<tr>
<td>2 &amp; 3</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
Comparison of Healthy and Cancerous Pancreatic Tissue Through Dissection and Imaging

Abraham N. Baker* and Daniel R. Olson, EdD
Northern Illinois University, DeKalb, Illinois
Abaker35@uic.edu

* Abe Baker was the recipient of a HAPS Student Grant in the spring of 2017 that funded his anatomical research for the completion of his Honors Capstone Project at Northern Illinois University. Grant recipients are encouraged to submit a summary of their work to the HAPS Educator.

Abstract
The pancreas is an organ that produces hormones regulating blood sugar levels and enzymes assisting with digestion. Despite these life-sustaining roles, a detailed study of the pancreas is often neglected in undergraduate courses in gross anatomy. To develop a better understanding of pancreatic structure, two pancreata, one with pancreatic cancer and one normal, were removed from cadavers donated to the Northern Illinois University (NIU) Anatomy program. These pancreata were serially sectioned by hand and scanned in a flatbed scanner to produce a series of images of their internal structures. ImageJ and 3D Slicer were used to produce 3D volume renderings of the pancreata. While multi-detector CT scanning is by far superior to scanning sections by hand, it is impractical for use at the undergraduate level. In the absence of multi-detector CT scanning, flatbed scanning can produce sequential images and 3D models of internal organ structures that serve to enhance anatomical education. doi: 10.21692/haps.2017.016

Key Words: pancreas, flatbed scanner, 3D slicer medical imaging, prosected cadavers

Introduction
To fully understand the structure and function of a tissue or organ, it is necessary to be able to see both its internal structure and its outer surface. For example, in emergency rooms, CT scans are routinely done to help assess a patient’s condition. CT scans and other medical imaging technologies all share one great advantage: they are non-invasive and non-destructive; a patient who gets a CT scan is digitally “sliced” but not physically sliced.

Educational programs in the anatomical sciences are also interested in obtaining high-quality images of internal organs. However, medical imaging technologies have several disadvantages for undergraduate education in anatomy. The scanners and associated computers required for many of these scans, which can cost a million dollars or more, are prohibitively expensive for use in undergraduate programs (Fornell 2010). There may be additional factors, such as the risk of radiation exposure and the need for extensive training to use the equipment, which make these technologies impractical for many educational settings.

In anatomy classes, students can see inside tissues and organs by observing prosected cadavers or by participating in dissections themselves. However, these approaches only allow students to see part of the tissue, not the entire internal volume that can be observed with a CT scan. Additionally, prosected cadavers can only be expected to last for six years (McCall 2016) without decaying, even under ideal conditions. In typical undergraduate lab environments, with less than ideal conditions, they may not last that long. This means that the preparation of cadavers must be a continuous process. In laboratories where students dissect cadavers, a cadaver can be expected to only last for one semester due to the destructive procedures required for students to uncover important structures.

The project described here aims to provide a way to create lasting images of internal structures that are practical for use in undergraduate anatomical education. The project describes the use of a flatbed document scanner to create serial scans of tissues and organs. The images produced can then be used to make 2D animations and 3D models similar to those of a CT scan, while preserving the original tissue color. While a similar approach has been used previously, for example in the BigBrain project, which produced more than 7,000 slices of brain tissue (Amunts et al. 2013), this project aims to develop methods that can be used in an undergraduate laboratory course in human anatomy.

Methods
Initial Scanner Testing and Setup
An Epson Perfection V550 Photo Scanner (Figure 1) was used for the flatbed-scanning portion of this project. An apple was used to test the scanner to confirm that the serial sectioning and flatbed scanning portion of the project. An apple was used to test the scanner to confirm that the serial sectioning and flatbed scanning method could produce satisfactory images and models (Figure 2a). The apple was marked with permanent ink longitudinally for orientation and latitudinally, at two millimeter intervals, as a target for slice thickness. Slices were sectioned with a scalpel and scanned at a 600 DPI resolution, with images saved as 24-bit TIFFs. This format
and resolution was used throughout the study. The scanner is capable of capturing images at 6400 DPI and 48-bit color. A higher resolution would have required more storage space than was available to the author and would not have resulted in a significant benefit for this project.

After scanning the apple, the scanner was waterproofed using silicone sealant caulk to prevent tissue fluids from leaking into and damaging the device. Water was used to confirm impermeability, and an orange was scanned to determine how to best scan wet tissue (Figure 2b). Water drops blur scan images; so all wet tissue was dried before each scan. The scanner glass was cleaned between scans using a microfiber cloth and glass-cleaner fluid if needed.

Procuring Pancreata

Two pancreatic specimens were used in this study. The cancerous pancreas (Fig 3, Right), which was removed by graduate students in an Advanced Gross Anatomy course, came from the cadaver of a 50-year-old woman who had died of metastatic pancreatic cancer. No tumors were observed on the surface of the pancreas. Part of the inspiration for this project was to investigate whether tumors were present inside the pancreas despite none being observed on its surface. The stomach of the cadaver was removed and left attached to the pancreas.

The healthy pancreas (Figure 3, Left) was removed by the author from an obese female cadaver whose right leg was missing due to an amputation. A large sore was present on the left leg of the cadaver. Peripheral nerve and blood vessel damage that can lead to foot amputation are known complications associated with obesity and peripheral sores may be symptomatic of advanced Type II Diabetes Mellitus (Brutsaert 2017). No extra observations or tests were made to confirm the presence of Type II Diabetes. During dissection, care was taken to remove the duodenum and spleen along with the pancreas in order to preserve the entire pancreas as well as structures such as the ampulla of Vater, the splenic artery and vein, and the bile duct.

CT Imaging

Since the flatbed scanning technique is destructive in that the tissue sample must be physically sectioned with a cutting tool, any comparisons to non-destructive scanning methods had to be conducted prior to the destructive technique. Each pancreas, along with its attached tissues, was packed into one of two plastic storage containers, partially filled with formalin, and taken to the Kishwaukee Hospital Radiology department. CT imaging was conducted using the “test scan” protocol normally used for quality assurance and scan data was exported to several CDs (Figure 4). Once the author and his mentor determined that no further scans were necessary, the project proceeded into its destructive phases.

Dissection

Extra tissue was cut away with a scalpel, hemostat, and scissors to make the pancreata easier to see in scans and models. Excised tissues included the stomach, the spleen, most of the duodenum (leaving approximately two inches bordering the ampulla of Vater) and any remaining mesentery, along with excess connective tissue. Some of these tissues were kept in preservative so they could be scanned after the pancreata. The rest of the excised tissues were discarded (Figure 5).
Sectioning and scanning the pancreata was accomplished in a manner similar to that which was used to scan the test fruit, though overall it was slower and more difficult due to the softer consistency of the pancreata compared to the apple. To prevent excess room light from changing the brightness of the scan image, the removable white plate normally stored in the lid of the scanner was supported by wooden blocks about three inches above the scanning bed (Figure 1). This method blocked out most of the excess light despite not being able to close the scanner lid as would be done for papers or small books. A previous method consisted of simply placing the lid plate directly on top of the specimen, but this led to an increase in the picture background brightness as the specimen decreased in thickness, creating an unwanted gradient in volume renderings.

Each pancreas was scanned using a coronal orientation to avoid the need to prop up the tissue and to create a clearer picture of the pancreatic duct running through the pancreas. Before beginning the sectioning process, the tissue was scanned on one face to produce an image of the outside surface. Dry-erase marker was used to mark orientation letters such as left, right, distal and proximal, onto the scanner glass and to make straight lines to help with positioning tissue for the rest of the scans.

A scalpel was used to shave away the surface of the tissue at a target depth of one to two millimeters. The tissue was placed onto the scanner glass cut-face down using the dry-erase markings to help position it as close as possible to the position of the previous scan. With the tissue properly positioned and the light-blocking lid in place, a scan was made and saved to the author’s laptop. Due to the high scan resolution, each scan could take a minute or more to complete. Up to five additional scans of the same section were necessary to re-adjust the tissue and better match the position of the previous section.

This process was repeated for each section of tissue. It was possible to break the sectioning processes up into several sessions by leaving the dry erase calibration markings on the scanning bed and placing the remaining un-scanned tissue back into the formalin until the next session. Unlike the test apple, it was not possible to make thin enough slices without shredding tissue, so most of the material from each already-scanned section was discarded.

Sectioning was stopped for each tissue once the sample thickness was too thin to cut safely by hand (usually two to three millimeters). To obtain an image of the opposite surface, the tissue was flipped over before scanning, and the resulting image was digitally flipped again in GIMP to match the orientation of the previous scans.

Two pancreata and one stomach were sectioned and scanned using this method (Figures 6a, 6b, 6c). The stomach required an extra step to facilitate sectioning and scanning. Crumpled paper towels were used to fill the lumen of the stomach and prevent tissue from the opposite side of the stomach from touching the scanner bed during scanning.
Image Visualization

While scans were being made, the default Windows image viewer, Photos, was used to compare the current scan image to the previous scan for positioning. The Gnu Image Manipulation Program (GIMP) was used to create animated GIFs of the scans. Making the exported GIFs small enough to send in emails required significant degradation of image quality and downsizing of image sizes.

Two programs were used to create 3D visualizations of the 2D scan image stacks. 3DSlicer (or Slicer) is an open-source DICOM visualization program that is usually used to view 3D volume renderings of data collected from multi-detector CT or MRI scanners (Fedorov et al. 2012). Slicer was used to view the CT data collected prior to sectioning (Figure 7a, 7b, 7c), but it was also used to view the flatbed-scanned images. First, all of the scans for a given structure were imported as an image stack. A value for image spacing was chosen based on the original height of the tissue (e.g. 20-30mm for a pancreas). A volume rendering was automatically generated by the program by stacking the images on top of each other with the given spacing. Gaps between each slice were automatically filled in based on the color and intensity of each pair of pixels in the images on either side of each gap (Figure 8).

ImageJ, which is a Java-based image measurement software suite (Schneider et al. 2012), was also used to produce volume renderings of the flatbed image stacks (Figure 9a, 9b). The main difference between ImageJ and Slicer is that ImageJ is able to automatically hide pixels of a particular range of colors (often the color of air or background material). This makes it possible to hide parts of the scanned images that are in the background, revealing tissue details without the necessity of adjusting the Region of Interest (ROI). Slicer is also able to perform this function, but it is preset to handle images from CT scans, making it more difficult to hide background colors from flatbed scan data.

Comparison of Healthy and Cancerous Pancreatic Tissue Though Dissection and Imaging

Image Rendering (Slicer) of normal pancreas, duodenum and spleen in the same container (later separated for sectioning). The pancreas is not visible in this rendering, but it was wedged between the visible spleen and duodenum. The white line was the calcified splenic artery running along the pancreas.

Image Rendering (Slicer) of flatbed-scanned cancerous pancreas.

Image Rendering (Slicer) of test apple.
for these observations is that the patient underwent a pancreaticoduodenectomy, also known as a Whipple procedure (Warshaw and Thayer 2004) to remove tumors within the pancreas. That would explain why no cancer was found within the pancreas or directly attached to the surface of the pancreas, even though the cause of death was listed as metastatic pancreatic cancer.

The pancreas from the cadaver without cancer was found to have a duodenal diverticulum, an extra pocket branching off the lumen of the duodenum, directly across from the ampulla of Vater. Duodenal diverticula are fairly common and most often harmless. Possible duodenal diverticula have been found in up to 20% of patients that undergo upper GI endoscopy. More than 90% of duodenal diverticula are asymptomatic (Shuck and Stallion 2001). However, if a diverticulum is present close enough to the ampulla of Vater, it has the potential to block the ampulla and cause a backup of digestive enzymes, potentially leading to pancreatitis and cholangitis. While it was not clear whether the ampulla of Vater itself was accidentally “missed” (not imaged due to lying between scanned sections), the pancreatic duct was clearly visible in the flatbed images, something that would have been very difficult to see on the CT images.

**Image Visualization**

CT data from the test scans was visualized in Slicer in both 2D and 3D views. For the tissue from the cadaver with pancreatic cancer, it was possible to selectively view the pancreas by using the “CT – Lung” preset (Figure 7a), and the stomach by using one of the “CT-Cardiac” presets (Figure 7b). This might have been made possible due to the difference in density of the two organs; the stomach is hollow while the pancreas is dense throughout. However, it was more difficult to view the healthy pancreas, possibly because it was surrounded by the spleen and duodenum (Figure 7c). The splenic artery running along the pancreas was clearly visible due to its calcification, which was verified by palpation during dissection and sectioning.

The 2D static images and animated GIFs were surprisingly helpful; scrolling forwards and backwards through the sequential images was very similar to viewing a CT scan in a coronal 2D view. The GIFs made from the scan images were similar to “cine mode” in DICOM viewers (Medixant 2016).

3D visualization of the flatbed scan data in this project did not produce models as high in quality as the volume renderings from CT data, but as a proof of concept it was a success. Both Slicer and ImageJ were able to load a stack of 2D scanner images and create a 3D volume rendering from it similar to the CT renderings. However, due to the high image resolution of the flatbed scans, both loading and rendering the images was slower than for the CT data. In both programs, flatbed image stacks took at least 5 minutes and 6 GB of RAM to load. Slicer was able to rotate and adjust the model much more quickly than ImageJ, which could take up to half a minute per
adjustment. With the default settings geared towards viewing CT and MRI scans, it was difficult to configure Slicer to show flatbed scan data with its original colors, while true color was the default in ImageJ.

In both programs, the third dimension of the rendering was much blurrier than the two dimensions provided by the original scans (Figure 8, 9b). Two factors contributed to this blurriness: the thickness of each section and the imperfect positioning of the sample for each scan. Despite the low resolution of one dimension, these models still demonstrated that this technique could produce 3D models of 2D scan data.

Discussion and Future Directions
Several challenges had to be overcome in order to scan human tissues on the flatbed scanner. First, while an apple is firm and does not easily deform, human pancreatic tissue is much softer and deforms with much less pressure. This made it challenging to not only use a scalpel to cut consistent sections, but also to then position the remaining tissue in the same place as before on the scanner bed. For each picture saved, often up to five pictures had to be taken before the position was acceptably close enough to the previous scan. Future work with the flatbed scanner could increase positional accuracy by using a fixative such as paraffin wax to prevent movement of the sample (Rolls 2017).

Slice thickness could be decreased and sectioning could be made more efficient by using a mechanical slicing apparatus, such as a macrotom to section tissue instead of using a scalpel by hand (Tot et al. 2005). However, there were some advantages to performing the sectioning by hand as opposed to using fixative and a sectioning device. Through manual sectioning, it was possible to learn about the tactile properties of the tissue in addition to the structure one could learn visually. For example, the pancreatic duct has a texture and stiffness similar to a small vein, but it seems thinner and easier to cut.

Slicer was used primarily in this project to produce volume renderings, which display all of the possible data. It can be difficult to only show one structure just by adjusting the ROI or color gradient settings. One way to create more specific models would be to create segmentations, which are 3D models of just part of a volume rendering. Segmentations are created by selecting or “painting” specific voxels that should be included as part of the 3D shape. This process is tedious to do by hand even with semi-automatic software tools to assist with selecting similarly-colored areas. However, segmentation is useful for quantitative tasks, such as measuring tumor diameter and volume (Velazquez et al. 2013) as well as creating permanent models that could be more easily-viewed by students, both digitally and physically since they can be 3D printed.

Image loading times in volume rendering software like Slicer and ImageJ could be reduced by re-exporting images at a lower resolution. Depending on the hardware available in an educational setting, it might not be possible to make the scan images small enough in size to use easily and still be high enough quality. Combined with the time it takes to learn how to use the software, these factors make it more practical to instead use pre-rendered data in the classroom. For example, animated GIFs and scrollable image sets could be provided to students either on a computer in the lab or online as downloadable files. Short videos could be made by recording a skilled user manipulating the volume rendering to point out specific structures. As mentioned above, segmentation could be used to print 3D physical models of specific structures.

This project has shown that it is possible to create a permanent visualization of the interior structure of human tissue similar to that of a CT scan using a consumer-grade optical flatbed scanner. These methods, along with the improvements described above, could allow an undergraduate anatomy course to create and use its own 2D and 3D scans, models and videos to enhance the learning and understanding of anatomy and physiology students.

About the Author
Abraham Baker graduated from Northern Illinois University (NIU) in the spring of 2017 with a BS in biology and minors in chemistry and psychology. He completed this research in Dr. Daniel Olson’s anatomy lab as part of his honors graduation requirements. Abraham will matriculate at the University of Illinois at Chicago (UIC) College of Medicine, Rockford campus in the fall of 2017.

Daniel R. Olson EdD is the Director of the Anatomy Laboratory in the Department of Biological Sciences at Northern Illinois University in DeKalb, Illinois.

Acknowledgments
The author would like to thank the NIU Biological Sciences Department and Dr. Daniel Olson for mentoring and support throughout this project. Thanks also goes out to the Human Anatomy and Physiology Society (HAPS) for their Student Grant and to Northwestern Medicine Kishwaukee Hospital’s Radiology Department for providing CT scans of the tissues used.

Literature Cited

continued on next page


Comparison of Healthy and Cancerous Pancreatic Tissue Though Dissection and Imaging
Core Concepts for Anatomy and Physiology: A Paradigm Shift in Course and Curriculum Design

Kerry Hull PhD¹, Murray Jensen PhD², Ron Gerrits PhD³ and Kyla Turpin Ross PhD⁴

¹Department of Biology, Bishop’s University, Sherbrooke, Canada
²Department of Biology Teaching & Learning, College of Biological Sciences, University of Minnesota, 5-220 Moos Tower, 515 Delaware St. SE, Minneapolis, MN 55455
³Professor and Program Director: Masters of Science in Perfusion program, Milwaukee School of Engineering, 1025 N. Broadway, Milwaukee, WI 53081
⁴Director of Graduate Training, Wallace H. Coulter Department of Biomedical Engineering, Georgia Institute of Technology & Emory University, 313 Ferst Drive, UAW 21 12, Atlanta, GA 30332
khull@hapsconnect.org, msjensen@umn.edu, rgerrits@hapsconnect.org

Abstract

The vast amount of information in the average anatomy and physiology course poses a challenge for instructors and students alike. Yet, studies show that students understand, retain, and transfer knowledge most effectively when courses emphasize depth over breadth. But, sacrificing breadth requires judiciously choosing which topics to teach. In this article we describe a potential curricular focus that may guide our choices: concentrating on core concepts. Also described by terms such as core principles, big ideas, or common themes, we define core concepts as foundational principles relevant to multiple situations that can be used to make predictions. Core concepts can help guide the design of our curriculum, class activities, and assessment in order to facilitate lasting, meaningful, and transferable student learning. doi: 10.21692/haps.2017.017

Key Words: core concepts; physiology; curriculum development; course design; inquiry learning

Introduction

As educators, the two questions that most inform our everyday practice are “what should I teach? and “how should I teach it?” The “how” of classroom science teaching has historically centered on lecture with varying degrees of visual aids (transparencies, Powerpoint, and now Youtube videos). The instructor is the curator and provider of information, while the students listen, take notes, and ask occasional unprompted questions. However, as the field of science education research has matured, the limitations of traditional lecture have become increasingly apparent (Bransford et al. 1999). Other instructional methods, often generalized as “active learning” have shown to be more effective at promoting deeper, more transformative (conceptual) learning (Michael et al. 2006). The landmark meta-analysis of Freeman et al. (2014) analyzed these and other studies comparing the effectiveness of the two approaches to teaching, and their findings were clear: Active learning wins; lecture loses.

While considerable work remains to be done in terms of refining how we teach, we would like to focus here on the first question: What should I teach? Anatomy and physiology is a scientific discipline rich in detail and facts. Historically, our ability to recall those details and facts has been equated with our understanding of our discipline. Online test banks still quiz students about the volume of urine produced by the kidney per day (McGraw Hill Education 2017), or the number of secondary bronchi (Biology Online 2017). We now know that recall is not the same as understanding. Studies show that students understand, retain, and transfer knowledge most effectively when courses emphasize depth over breadth (Schwartz et al. 2009). But, now that we cannot teach everything in a shallow fashion, the question of What to Teach becomes even more difficult to answer. In this article we describe a potential curricular focus that may guide our choices: concentrating on core concepts. Also described by terms such as core principles, big ideas, or common themes, we define core concepts as foundational principles relevant to multiple situations that can be used to make predictions. Using key concepts fosters understanding and retention, and allows knowledge to be transferred between different domains (Michael et al. 2017).

Core Concepts in Science Education

Organizing curriculum around core concepts is not a revolutionary idea; this approach (alongside active learning) is advocated by policy documents addressing teaching and learning at all levels (K-16) and all STEM disciplines. Starting with the most general and transitioning to more Biology-centered lists, examples include:

1. New Generation Science Standards (NGSS) proposes 7 “cross-cutting concepts” relevant to all STEM fields, and describes how student understanding of each idea should develop over the course of K-12 education (NGSS Lead States 2013).
2. Scientific Foundations for Future Physicians recommends that pre-medical programs emphasize competencies rather than specific content (Association of American Medical Colleges and the Howard Hughes Medical Institute 2009).


5. The NSF sponsored “Conceptual Assessment in the Biological Sciences (CAP)” proposes eight core concepts, adding homeostasis, cell theory, and causal mechanisms to the Vision and Change list (Michael et al. 2008).

So, instructors of first-year biology courses have multiple (yet largely consistent) lists of key concepts to guide them. The onus is now on instructors of more specialized courses in the biological sciences to derive their own lists. Some research groups have written preliminary lists to guide the development of core concepts: Evolution, Energy and Matter, Information flow, Structure and function, and Systems (AAAS 2010).

Core Concepts in Physiology: the Conceptual Assessment of Physiology (CAP) Group

The process by which Michael and colleagues came up with their list of Physiology core concepts is comprehensively described in their monograph (Michael et al. 2017) and in a shorter article (Michael and McFarland 2011). In brief, a small group of educators involved in the Conceptual Assessment in Biology project developed an initial list of nine physiology core concepts (Michael et al. 2009). Following consultations with a wide variety of educators, they expanded the list to include the fifteen core concepts shown in Table 1 (Michael and McFarland 2011). These concepts include relatively concrete concepts (e.g. flow down gradients), broad themes (e.g. physics/chemistry), and soft skills (e.g. scientific reasoning).

In order to render core concepts useful to educators, three highly ranked core concepts were selected for additional development: flow down gradients, homeostasis, and cell-cell communication. Each was ‘unpacked’ into a validated conceptual framework, a hierarchical list of component concepts and sub-concepts (McFarland et al. 2016). For instance, one of the five homeostasis components is Homeostatic processes require a sensor inside the body; a sub-concept is Sensors are always active. They accompany each list with definitions, visual representations, and relevant physiologic situations, everything instructors need to fully understand the concepts. (Later in this article we discuss ways to use the core concepts in teaching). The remaining twelve concepts have not yet been unpacked, and Michael et al. (2017) have called on the physiology community at large to continue these efforts. However, even now their list of core concepts can serve as a framework for structuring our courses and even our exams.
Core Concepts for Anatomy and Physiology

While the CAP list has been validated and has received widespread acceptance, many of us teach combined courses in Introductory Anatomy and Physiology. To this end, the Human Anatomy and Physiology Society (HAPS) has developed a list of Fundamental Process and Learning Goals that are meant to “form the unifying foundation for all topics in anatomy and physiology and are to be emphasized throughout Anatomy and Physiology I and II” (HAPS 2017a). This list is composed of eight goals and includes items such as “Develop a vocabulary of appropriate terminology to effectively communicate information related to anatomy and physiology”, and “Interpret graphs of anatomical and physiological data”. HAPS also includes an additional three “broader process goals” that are meant to stress skills developed throughout a curriculum (HAPS 2017a). One example of these is “Demonstrate information literacy skills to access, evaluate, and use resources to stay current in the fields of anatomy and physiology”. Although there is some overlap between the Core Concepts in Physiology and the HAPS Learning Goals, the latter are quite general and emphasize transferable skills.

### Table 1: Core Concepts of Physiology (Michael et al. 2017)

<table>
<thead>
<tr>
<th>Core Concept</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>Evolution</td>
<td>The mechanisms of evolution act at many levels of organization and result in adaptive changes that have produced the extant relationships between structure and function.</td>
</tr>
<tr>
<td>Homeostasis</td>
<td>The internal environment of the organism is actively maintained constant by the function of cells, tissues, and organs organized into negative feedback systems.</td>
</tr>
<tr>
<td>Causality</td>
<td>Living organisms are causal mechanisms (“machines”) whose functions are explainable by a description of the cause-and-effect relationships that are present.</td>
</tr>
<tr>
<td>Energy</td>
<td>The life of the organism requires the constant expenditure of energy. The acquisition, transformation, and transportation of energy are essential functions of the body.</td>
</tr>
<tr>
<td>Structure/function</td>
<td>The function of a cell, tissue, or organ is determined by its form. Structure and function (from the molecular level to the organ system level) are intrinsically related to each other.</td>
</tr>
<tr>
<td>Cell theory</td>
<td>All cells making up the organism have the same DNA. Cells have many common functions but also many specialized functions that are required by the organism.</td>
</tr>
<tr>
<td>Levels of organization</td>
<td>An understanding of physiological functions requires understanding the behavior at every level of organization from the molecular to the social.</td>
</tr>
<tr>
<td>Cell-cell communication</td>
<td>The function of the organism requires that cells pass information to one another to coordinate their activities. These communication processes include endocrine and neural signaling.</td>
</tr>
<tr>
<td>Cell membrane</td>
<td>Cell plasma membranes are complex structures that determine what substances enter or leave the cell. They are essential for cell signaling, transport, and other processes.</td>
</tr>
<tr>
<td>Flow down gradients</td>
<td>The transport of “stuff” (ions, molecules, blood, and gas) is a central process at all levels of organization in the organism, and a simple model describes such transport.</td>
</tr>
<tr>
<td>Genes to proteins</td>
<td>The genes (DNA) of every organism code for the synthesis of proteins (including enzymes). The genes that are expressed determine the functions of every cell.</td>
</tr>
<tr>
<td>Interdependence</td>
<td>Cells, tissues, organs, and organ systems interact with one another (are dependent on the function of one another) to sustain life.</td>
</tr>
<tr>
<td>Mass balance</td>
<td>The quantity of “stuff” in any system, or in a compartment in a system, is determined by the inputs to and the outputs from that system or compartment.</td>
</tr>
<tr>
<td>Physics/Chemistry</td>
<td>The functions of living organisms are explainable by the application of the laws of physics and chemistry.</td>
</tr>
<tr>
<td>Scientific reasoning</td>
<td>Physiology is a science. Our understanding of the functions of the body arises from the application of the scientific method; thus, our understanding is always tentative.</td>
</tr>
</tbody>
</table>
In an attempt to identify content-based core concepts in Anatomy, one of us led a workshop at the 2015 HAPS Annual Meeting (Jensen 2015). The participants identified three potential anatomy-specific additions to the CAP list: Inside vs. outside, medical terminology, and body spaces and cavities. However, aside from this preliminary work, we are not aware of any published list of Core Concepts for Anatomy and Physiology, either validated or invalidated. Moreover, Michael et al. (2017) acknowledge that instructors generally pick-and-choose which concepts they will emphasize. Instructors may thus want to develop their own list of core concepts to scaffold their courses. For example, Table 2 outlines the “key ideas” developed by one of us to guide textbook authorship activities. This preliminary effort can provide an optional starting point for instructors until the A & P community develops a consensus list.

Table 2: Examples of Key Ideas of Anatomy and Physiology

<table>
<thead>
<tr>
<th>Key Idea</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Structure-Function</td>
<td>The anatomy (structure) of an element impacts its physiology (function).</td>
</tr>
<tr>
<td>2. Levels of Organization</td>
<td>All living things are organized from very simple levels (e.g., atoms) to very complex levels (e.g., an organism). Anatomy and physiology can be studied at any of these levels.</td>
</tr>
<tr>
<td>3. Homeostasis and Negative Feedback</td>
<td>Despite changing environmental conditions, critical body functions such as blood pressure and temperature are maintained within tight limits. Negative feedback is a control system based on information returning to a source. It reverses any upward or downward shift in a particular body condition. Negative feedback loops require a sensor, control center, and effector.</td>
</tr>
<tr>
<td>4. Barriers</td>
<td>Barriers help the body maintain distinct environments. For instance, the skin and mucous membranes separate the inside of the body from the external environment, and the plasma membrane separates the cytosol from the extracellular fluid.</td>
</tr>
<tr>
<td>5. Gradients and Flow</td>
<td>The movement (flow) of a particular substance is promoted by gradients and opposed by resistance.</td>
</tr>
<tr>
<td>6. Water</td>
<td>Water participates in many physiologic processes. Understanding its characteristics (e.g. conductivity, ability to act as a solvent) is key to understanding these processes.</td>
</tr>
<tr>
<td>7. Enzymes and Chemical Reactions</td>
<td>Most chemical reactions require the actions of enzymes. The activity of specific enzymes can be increased or decreased in response to changing body conditions. The concentrations of reactants can also alter the speed and, in some cases, the direction of the chemical reaction.</td>
</tr>
<tr>
<td>8. Energy</td>
<td>Organisms need to generate and use energy. Tracking energy and matter flow through systems is a key part of understanding physiology.</td>
</tr>
<tr>
<td>9. Genes Code for Proteins</td>
<td>DNA is the cell’s master blueprint, determining the body’s structures and functions. Mutations, changes in the DNA sequence of a gene, can change the shape of the resulting protein, or even stop it from being synthesized.</td>
</tr>
<tr>
<td>10. Causation and Correlation</td>
<td>Two events may be correlated (i.e., frequently occur together) without one event causing the other. Establishing causation involves specifying a sequence of interactions linking the cause to the effect.</td>
</tr>
<tr>
<td>11. Adaptation</td>
<td>Organisms adapt to the environment; that is, their structure, function, or behavior changes in response to changes in their environment. Adaptation often results from injury, and helps protect against future damage.</td>
</tr>
<tr>
<td>12. Communication</td>
<td>The body uses chemical and electrical signals to convey information. Chemical signals alter the activity of target cells by binding specific receptors.</td>
</tr>
<tr>
<td>13. Mass Balance</td>
<td>The amount of material in a system depends on both inputs and outputs. With few exceptions, the adult body keeps storage pools of most substances relatively constant by matching input and output.</td>
</tr>
</tbody>
</table>

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Core Concepts vs. Learning Outcomes

Key concepts are distinct from learning outcomes, which are hierarchical lists of tasks students should be able to perform using important concepts and facts, generally organized by body system. A given key concept is relevant to multiple learning outcomes. The American Physiology Society (APS) and the Human Anatomy and Physiology Society (HAPS) have invested considerable effort in developing comprehensive lists of learning objectives and outcomes for physiology and anatomy and physiology, respectively (Carroll 2016; HAPS 2017b; HAPS 2017c). Each specific learning outcome is associated with a cognitive level, as defined in an accompanying document (HAPS 2017d). Since learning outcomes are manifestations of key concepts in different body systems, it is possible to link them to both process-oriented learning goals and content-oriented key concepts. For instance, 11 specific learning outcomes within the Homeostasis module (module B) are linked to HAPS Content Goal 3 (Recognize and explain the principle of homeostasis and the use of feedback loops to control physiological systems in the human body). Considering the CAP key concepts, the Flow down gradients key concept applies to HAPS outcomes relating to diffusion (C.8.1), action potentials (H.4), blood pressure (K.14) and pulmonary ventilation (M.3).

Core Concepts: From Theory to Practice

Core concepts can help guide the design of our curriculum, class activities, and assessment in order to facilitate lasting, meaningful, and transferable student learning. Instructors can decide when and how to introduce their selected core concepts; introducing too many concepts at the beginning of the course may be overwhelming. One of us (Hull) introduces three concepts (homeostasis, mass balance, and flow down gradients) in the first week of physiology class, using a group exercise derived from Harold Modell’s work (Modell 2000). Other core concepts are introduced as needed. For instance, stability and change (an NGSS key concept) is presented during the discussion of the bicarbonate reaction in the respiratory system unit. Conversely, one of us (Jensen) organizes an entire introductory course around the key concept of homeostasis.

The core concepts, alongside the relevant published learning outcomes (APS or HAPS), can also guide the choice of which topics to cover. Michael et al. (2017) recommend that the use of core concepts be reflected in course learning outcomes. We propose that they could also be used to pare down learning outcomes; if the outcome does not address a core concept, is it really that important?

The design of learning resources can similarly be organized around core concepts. Michael et al. (2017) provide a model for this process. They describe active learning techniques that incorporate core concepts into the teaching of three important, yet difficult, topics: acute blood pressure regulation, ventilation, and the hypothalamo-pituitary axis. Michael et al. note, “What is needed is the development of learning resources that focus on core concepts as well as on specific physiological mechanisms” (Michael et al. 2017 p.149). While they are not coded for particular key concepts, the HAPS Teaching Tips database (HAPS 2017e) contains many active learning resources to help address this need. The authors of this article are developing guided inquiry lessons on topics such as the regulation of blood pressure, and membrane physiology. Our long-term goal is to provide HAPS members with a library of curriculum materials that:

1. Address the core concepts and HAPS learning outcomes.
2. Promote good conversation among students.

To this end we are welcoming submissions for a Special Fall issue of the HAPS Educator, which will focus on curriculum. See the full announcement on page 152.

Core Concepts: From Theory to Practice (continued on next page)
core concepts. Such intentional design might change some courses a lot, and others a little. We think it is a discussion worth continuing and a concept worth trying.

About the Authors
Kerry Hull teaches anatomy, physiology, advanced physiology, and exercise physiology in the Department of Biology at Bishop’s University in Sherbrooke, Quebec.

Murray Jensen teaches entry-level anatomy and physiology courses in the College of Biological Sciences at the University of Minnesota.

Ron Gerrits teaches Physiology in the Electrical Engineering and Computers department at the Milwaukee School of Engineering.

Kyla Ross teaches Physiology at the Georgia Institute of Technology.

In addition to their individual research interests, they are collaborating on a research project developing and evaluating guided inquiry activities for upper-level physiology courses.

Literature cited


Do You Know What It Means? Words, Meaning and Infograms

Vasiliy Kolchenko, MD, PhD
Professor, Department of Biological Sciences, New York City College of Technology, The City University of New York, P313, 300 Jay St., Brooklyn, NY 11201, tel. 718-260-5954
vkolchenko@citytech.cuny.edu

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Abstract
The paper explores the relationships between the essential cognitive skills: memory, abstract thinking and imagination, in the context of Infogram learning. Infograms are the symbolic graphic summaries of the material that use pictograms, abbreviations and key words for encoding and multiple retrieval of information. They facilitate meaningful learning and provide a ‘big picture’ of the topic. Infograms are neither concept maps nor infographics but can use elements of both in the process of creating the overall graphic symbolic narrative that covers the curriculum. All cognition is based on symbols that include words, abbreviations and pictograms. All symbols are abstractions. Infogram learning helps in developing the abstract thinking skills. Typical cognitive problems and successes are discussed. One way of detecting the problems is conducting the regular one-minute interviews with students in the classroom. Our students have the language, imagination and memory that need to apply to the content of the course. doi: 10.21692/haps.2017.018

Key Words: education, Infograms, retrieval, graphics, symbols

Introduction
In the beginning of each semester, I tell my Anatomy and Physiology students that for them it is also a foreign language class. The language we are studying is the terminology of medicine and human biology. It is based on Latin and Greek and may sound strange and intimidating. Students may have heard some of these words before but there will be hundreds of completely new names, often hard to pronounce, understand, and use.

Obviously any unfamiliar subject or field of knowledge has its own language or terminology that the learners need to master, but Anatomy and Physiology may be the champion in this respect. In my rough estimation, our curriculum demands from students to learn dozens of new names every week. This linguistic load accumulates very quickly and soon can become overwhelming.

On the other hand, we are not at liberty to reduce the load. It is the human body, and instructors cannot or, at least, should not skip a few organs or functions for the sake of emphasizing the rest. At this point, I ask my students, “Would you like your loved ones or yourself to be in the hospital at the mercy of nurses and doctors who never learned their Anatomy and Physiology? Or maybe they learned the right side of the body but not the left? Who wants this kind of health care for your family?” No students ever said that they did. Therefore, the challenge is accepted, not only to learn the terminology but also to understand and use the names correctly.

Success or Failure?
However, this is easier said than done. Of course, good intentions are always there. In my many years of teaching, I am yet to meet students who come to class hoping that they would fail. Some expect failure, based on their previous experiences, but deep down they still hope for a miracle, a fresh start. Then differentiation begins. In a diverse classroom, there will be some students who never show up or come to school occasionally.

Other students will miss a few classes, but their physical presence does not mean that they are truly engaged. The body is there, while the mind is wandering. Even without the electronic distractions of cell phones, tablets and laptops, even with their eyes on the teacher, these students may think about completely unrelated subjects. For example they may be contemplating buying shoes, meeting their boyfriends-girlfriends, and anything of interest, either fleeting or obsessive. In their lives, there are jobs, family emergencies, health scares, mental issues, various addictions and, in some cases, even homelessness and violence. The combined pressures grow and can make effective learning nearly impossible.

Sometimes we can help, and sometimes we cannot. Most of the time, we do not even know what is going on. I would say that the numbers of students who drop or fail the class for reasons of this nature may go from zero to 10-20 percent, depending on the student population.

The majority of students actually listen, participate and do the work. Many succeed, getting high grades. Others do reasonably well. There is also a group of students who, admittedly, work hard but do poorly on the exams. “I studied so much,” they tell you, “How could I fail? Can I see my test paper?” Usually they explain this request by saying that they want to learn from their mistakes, but I suspect that many of
them want to make sure the teacher graded the test correctly, so much are they surprised by their low grades.

It has been well documented that most students, particularly those with lower grades, tend to overestimate their future exam results (Clayson 2005). They believe that they learned the material but in reality they did not. The exam questions sounded familiar to them but it does not mean that their answers to the questions were correct.

Another big surprise comes if our students take an independent cumulative final exam, similar to the HAPS comprehensive online examination (HAPS 2017). The national averages for this exam are usually around 50 percent, maybe somewhat higher. Keep in mind that these are the averages of the selected schools and instructors, willing to pay for the test and take the risk of getting relatively low scores. In a less ambitious classroom the results may be even lower.

In my school, the passing grade for the course is 60 percent. The majority of the students get a passing final exam score. Most other schools do not fail the majority of their students either.

How can we explain this discrepancy? If the independent exams are objective and fair (and there are no reasons to doubt this), then there is one plausible explanation, that our own exam grades are significantly inflated overestimating what the students actually learned.

How is it possible? Probably we are subconsciously teaching to the test, our test. When the exam questions cover what we did not emphasize in class or the questions are simply rephrased, the students get confused and discouraged.

**Words and Meaning**

This brings us back to the question of *knowledge* and *understanding*. There are also *application*, *analysis*, *synthesis* and *evaluation* popularized by the Bloom’s Taxonomy (Bloom *et al.* 1956). They all reinforce each other and cannot be easily separated. However, it is hard to emphasize the analysis or evaluation skills when the students do not know the basic language of the subject. How can we prevent them from simply memorizing a bunch of words without clear understanding of the meaning?

Richard Feynman, the Nobel laureate in physics, summarized his teaching experience in a Brazilian university the following way: “After a lot of investigation, I finally figured out that the students had memorized everything, but they didn’t know what anything meant.” (Feynman 1985)

This is typical for the failing students who are convinced they studied hard. It may be true that they learned a lot but they barely know what it all means. And what about our A-plus students that get a B or a C grade on the independent exam? They know much more, nearly everything, but the meaning of that ‘everything’ often escapes them as well.

For some students the problem is the inability to connect the dots. Like in the story of blind people touching the elephant, there is no basic understanding of what the elephant is; instead, there are many isolated bits and pieces of seemingly unrelated information. After learning their independent exam grades, these student in this category are usually humbled and embarrassed, and so are their instructors.

But what can be done? First it is important to learn more about the problem, a step at a time:

**Step One:** How can the instructors find out who has the problem and to what extent? In theory, there may be some very capable, motivated and hard-working students that could figure out all the complexities of the topic by using a good textbook with the minimal help from the teacher. Unfortunately, there are not that many ideal learners in our classrooms. As for others, our understanding of their cognitive problems is usually based on the exam and assignment grades. There is no time to interview every student on a regular basis.

**Step Two:** What is going on in the minds of the students as they study and take exams? Maybe even more importantly, what is NOT happening but should be happening? Again, it is hard to learn without questioning the students individually.

**Step Three:** What cognitive tools can help? My answer to this question was the instructional materials called Infograms, first described in this journal (Kolchenko 2015). As I explained in the paper, Infograms helped me approach the first two questions as well.

**Meaning and Infograms**

Infograms are the visual snapshots of the topic (Figure 1). To design them effectively, I had to use graphic symbols: pictograms, abbreviations and key words, supplemented by the explanatory text, side notes, slides, term list and homework assignment. (The text is particularly helpful if students missed the explanation in class and study the Infogram on their own.) The resulting one-page graphic symbolic summary appears to be an invaluable tool both for learning new information and for recalling what was learned.
Infogram-based recalling, or retrieval of information, becomes a creative process as soon as the graphic details are significantly reduced and there is a need to fill the information void using memory and imagination. The value of retrieval practice for meaningful learning has been demonstrated repeatedly (Karpicke and Blunt 2011), but this practice is usually limited to using quizzes and exams for testing and self-testing. Using Infograms provides a new way for the cued retrieval; they are designed for fast and efficient reviewing of the material based on the graphic symbols. Infograms also provide a ‘big picture’ of the topic at a glance, emphasizing the relationships among the concepts and helping ‘to connect the dots.’

Infograms are not concept maps. Concept maps (Fig. 3) are usually limited to the names of concepts, in boxes, connected by the arrows-relationships (Novak and Gowin 1984). This feature is present in many types of graphic representation and it was used long before the term ‘concept mapping’ was coined.

In my experience, concept maps were of special interest to the instructors and students who knew the subject well. For the new learners, they were quite helpful illustrating simple topics with a small number of concepts and connections. As the number of boxed names and arrows between the boxes was increased, the concept maps became complicated graphic webs of limited educational value. For most students, they were rather confusing and off-putting. In this case, a ‘big picture’ obscured the meaning of the topic. The use of Infograms, is supposed to clarify the meaning at a glance.

This is achieved by drastically reducing graphic noise and, inevitably, increasing graphic abstraction.
For example, Figure 1 and Figure three cover the same topic, *Body Directional Terms and Planes*, but in a very different way. Figure 1 shows the Infogram (top) and the term list (bottom). Figure 3 shows the concept map.

Figure 2 presents the pictograms used in the Figure 1 Infogram. They are abstracted views of the human body: frontal, lateral and superior. The dotted vertical line is the body midline.

The Infogram also uses the term abbreviations. Capital C and P are used twice: C for *cranial* and *caudal* and P for *proximal* and *posterior*. The names are not confused because the position of the initials relative to the human body pictograms has additional meaning that eliminates ambiguity e.g. form the infogram, it is clear that *cranial* is closer to the head, etc.

As you compare Figure 1 and Figure 3, which one is more abstract? The full names in the concept map are less abstract that the initials in the Infogram. But the initials help you recall full names, while there is nothing to recall when the names are already given. In this sense, the greater abstraction of the Infogram is useful for learning.

Furthermore, the position of the initials relative to the pictograms of the human body help you recall the meaning of each name (*superior* means above, *inferior* means below, etc.), while the concept map has little meaning in this respect, unless you already know what the terms mean. In this sense, the concept map is more abstract and less useful for a student.

Finally, the visual impression: for a new learner, the concept map seems crowded and complicated in comparison to the compact and simple Infogram. Here, the visual meaning is more unique, memorable and intuitive.

*Infograms are not infographics*. The emerging field of *infographics* has one central goal and that is to improve graphic design of data representation. In other words, this is an effort to make data graphs and tables more readable and less misleading (Tufte 1997). It applies to all media e.g. video, online, slide presentations, print and others.

As important as it is, *infographics* are mostly limited to data representation and focus on any consumer of data, for example, designing the most effective infomercials. Infograms, on the other hand, are focused on the student and the content of learning. They can use some elements of infographics and concept mapping such as simple data graphs and tables; a few boxes connected by arrows, but they are not limited to them. Here, the goal is different. This is an attempt to create an overall graphic symbolic narrative that covers the curriculum, including all needed data and concepts, in a comprehensive, easy-to-use and intuitive manner.

**Symbols and Cognition**

The key is the role of symbols in human cognition. My main idea is this: all cognition, including school learning, is based on symbols. Any thinking is symbolic; it cannot be otherwise.

What does it mean? Symbols, for our purposes, are any sensory or mental signals that represent something else – anything else – in the mind of the learner. For example, all words are symbols, either auditory in oral speech or visual in writing, because any word represents something else, either in the world of reality or in the world of ideas. Abbreviations, popular since ancient times, are the symbols of the symbols (Kolchenko 2016). Graphics like pictograms are non-verbal visual symbols that may have multiple meanings, for example, an arrow or a cross (Kolchenko 2015).

Symbols are always abstractions of the meaning; they abstract the meaning by substituting it with something else. A little can represent a lot. A lot can represent a little. In the process, details are necessarily lost and an abstraction is born. The extent of abstracting can differ. As it grows, there may be a problem with comprehension (‘connecting the dots’).

continued on next page
Then learning is not just memorizing the symbols, for example, anatomy terms. It is also creating associations between the symbols and their meaning in a complex and ever-changing multi-symbolic matrix.

How does it happen in the learner’s mind? We do not have a magic window to see it happening, but it is possible to collect a lot of circumstantial evidence. Using Infograms, I developed a technique of briefly interviewing every student in my class once a week. The objective is to check the knowledge and understanding of the Infogram material we are studying.

**One-minute Interviews**

One-minute interviews are done in the Anatomy and Physiology lab where we have about 20 students. The lab runs for two and a half hours. As the students are busy taking a weekly quiz for about twenty minutes, I call them to my desk, one by one, and ask a few pointed questions about the Infogram material. Students usually respond very fast because most of them know and understand the Infogram, and if they do not, it is obvious almost immediately.

Clearly, there is no way I could do these one-minute interviews without the Infograms. But even with them it took me a few semesters to gradually learn how to do it right. The first question was simple: Do you know what the infogram means? Originally I was able to talk to a few students during the quiz (they did not mind), but eventually I improved my technique enough to have more and more of these diagnostic conversations.

During the last semester, Spring 2017, I interviewed everybody every week. Now all students expected me to talk to them, and if I missed someone, that person would remind me later saying, “You didn’t talk to me today!” Then I would find a minute (in the lab, it is not that hard) and ask my questions.

I marked the outcome for every student every time. From the very beginning, it was clear that there might be different levels of comprehension, from ‘a student who knows nothing’ to ‘a student who understands everything.’ Those extremes rarely happen, but other levels are not uncommon. In a class of students the range of comprehension means that some students can:

1) Know the appropriate terms but not know the meaning of the terms.
2) Know the meaning of terms and give definitions, verbatim.
3) Know the meaning of terms and explain it in their own words.
4) Explain relationships between concepts, compare and contrast.
5) Give examples and describe applications.
6) Explain seemingly unrelated examples using the knowledge of the material.

**Cognitive Problems and Successes**

Using this questioning process, I was able to find out, in real time, who had a learning problem and what kind of problem it was. I gave students advice, individually, and monitored the progress of every student. That did not mean that all the problems were solved right away. However, I was able to observe how persistent the problems were, including the problems of the desperate attempts to memorize every word rather than understand and imagine the content.

One of the cognitive problems I have observed concerns the entrenched learning habits that a student develops during the first twelve years of schooling. Many students truly believe that memory is the most important learning skill. They say so in the surveys (unpublished results) and they practice this belief consistently, no matter what the instructor suggests. Changing a twelve-year old cognitive routine is not an easy one-semester task.

On the bright side, the one-minute interviews provided a tool that has allowed me to continue the investigation. It also shows that the majority of students are on the right track. This may explain a couple of recent messages from my former students, which were sent long time after they got their course grades.

One student requested:

> “I am desperately asking you if you have Infograms for Anatomy and Physiology II. Please, please send (them) to me. I used to be an A student with your Infograms’ help. I feel I am getting lost during this semester.”

Another student wrote, one year after completing the course:

> “I decided to go back to the Infograms to refresh my memory and so far, I remember most of it! Obviously, there are a few things that I have to look for in the text but a good portion of it I remember just from the Infogram pictures. I thought I should share that since it’s an ongoing project that you are still working on and I seriously think it’s great that I had the opportunity to be in your class and learn from the Infograms.”

**Conclusion: Memory or Imagination?**

Of course memory is important. It is the foundation, which is always implied. Weak memory can be a big problem for a student. There is also a condition called amnesia (no memory), but the patients with this condition are not likely to take our course. You can say that some of our students have a peculiar kind of selective amnesia, especially after the exams, with no retention of knowledge whatsoever. But the same people remember a lot of other information without much effort, for example, anything related to popular culture. It is hard to say that their memory is weak, except maybe for the science curriculum.

The reason, I think, is not even the lack of interest but the failure of imagination. Their imagination is bold in the movie
theater but timid in the science lab. This is why the scientific symbols-abstractions are rarely connected to the reality in their minds. For this, you need your imagination free and strong. Einstein once said, “Imagination is more important than knowledge.” (Einstein 1929). Surely he did not mean that knowledge is not important. He just emphasized the priority. Imagination makes the abstract thinking possible, associating abstract symbols with the reality and each other.

Abstract thinking is the most wanted cognitive skill in sciences, but it is not limited to dwelling in complete abstractions. It is also the constant transition between the real and the abstract that we continuously practice with Infograms, and imagination makes it smooth and easy. Is abstraction difficult? All words are abstractions, and this means that anyone who mastered language is capable of abstract thinking. When I tell my students that imagination is more important than knowledge, they are genuinely surprised. The good news is they have everything they need to become good learners; they have language, imagination and memory. They just need to apply all of this to the subject matter of anatomy and physiology.

About the Author

Vasiliy Kolchenko is a Professor of Biology at New York City College of Technology, The City University of New York. Vasiliy teaches Anatomy and Physiology and Bioinformatics. His research includes biosensor development and graphic representation in science education. He also writes and performs music. This is his Teaching Science song: https://www.youtube.com/watch?v=CpeI5wHvKE4

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Does Active Learning Achieve Desired Outcomes: Conflicted Pedagogy?

Mari K. Hopper, PhD
Dept. of Cellular and Integrative Physiology, Health Professions Room 3061, Indiana University School of Medicine – Evansville, Evansville, IN  47712
mkhopper@iupui.edu

Abstract
Accreditation organizations have asked for increasing amounts of “active” and “self-directed” learning as a means to enhance student engagement and development of higher order skills. In response to calls for reform, colleges and universities have modified their curricula to include more student-centered learning opportunities and less reliance on traditional didactic lecture. Although the preponderance of evidence indicates the effectiveness of active learning strategies, there are conflicting reports in the literature. This article shares possible reasons for contrasting results and encourages all faculty to utilize a scholarly approach in evaluating methods applied in the classroom. doi: 10.21692/haps.2017.019

Key Words: active learning, reform, evaluation, assessment, scholarly approach

Marie Hopper presented a workshop on this topic at the 31st HAPS Annual Conference in Salt Lake City, Utah in May 2017.

Introduction
Over the last decade or so, organizations including the American Association for the Advancement of Science, the National Research Council, and the Association of American Medical Colleges have called for reform in education. To better prepare our students for professions in the sciences, reformers are asking faculty to more actively engage our students in their learning.(Lawley et al. 2005; Martin et al. 2004, Woodin et al. 2010). In response to appeals for reform, colleges and universities have called upon faculty to generate student-centered classrooms that rely less on traditional didactic methods. Some schools have elected to base their entire curricula around a single student centered approach, such as the flipped classroom, or problem based learning (Hartling et al. 2010, McLaughlin et al. 2013). Others use a variety of approaches, but outline specific policies such as the number of contact hours devoted to non-didactic sessions. Non-didactic sessions are often referred to as “small group” or “active learning.”

A few years ago, our medical college announced plans to reform the curriculum. Reform efforts aimed to meet the Liaison Committee on Medical Education (LCME) standards for accreditation including standard ED-5-A.

Standard ED-5-A states that:
A medical education program must include instructional opportunities for active learning and independent study to foster skills necessary for lifelong learning.

Reform efforts resulted in all courses devoting at least fifty percent of contact time to non-didactic, or active learning activities. As a faculty member heavily involved in authoring materials for courses in the new curricula, many questions came to mind:

1. How do we define active learning, and what are the objectives for incorporating this approach?
2. What activities fulfill the requirements for active learning, and what evidence (data) do we have that this strategy works?
3. Are there times when active learning does not achieve its objectives, and if so, what factors contribute?
4. Does faculty training impact the success of active learning strategies? If so, what defines “best practice” in faculty development?

In search of answers, I began to reflect on my prior work. Over a decade ago, and largely in response to early calls for reform, I began to make changes in the way I taught. As I set out to implement change, I first questioned how we define active learning, and what would it look like in my classroom.

1. How do we define active learning, and what are the objectives for incorporating this approach?

In reviewing the literature, I found many different definitions reported, but they shared common elements (Bonwell and Eison 1991, Freeman et al. 2014). Perhaps the following definition provided by Freeman and colleagues best represents what active learning entails, and includes the objectives for development of higher order skills:
“Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.”

As I set out to include more active learning in my courses, I began to question my peers about their practices.

2. What activities fulfill the requirements for active learning, and what evidence (data) do we have that this strategy works?

As I asked my peers what active learning “looked like” in each of their respective classrooms, the answers were quite diverse. Similarly, activities reported in the literature as active learning varied greatly (Table 1) (Bonwell and Eison 1991, Freeman and Jessup 2004, Freeman et al. 2014, Froyd 2008, Hopper 2015, Michael 2006). Active learning exercises ranged from simple, low tech, to highly organized, and technologically advanced practices. As there are such a variety of activities that can be considered as active learning, it is perhaps best to think of active learning as an approach, rather than a method or activity. Based on what I learned at the time, I believed that I could take nearly any classroom activity and enhance or add active learning elements simply by shifting the focus for learning from the teacher to the student. I made adjustments in my teaching and incorporated a number of active learning exercises including minute papers, think-pair-share activities, student self-assessment, and formative quizzes (Hopper 2015).

Table 1. Active learning activities reported in the literature

In order to evaluate the effectiveness of new approaches, I commenced a study that evaluated student engagement in all classes I taught over the course of one year. The study utilized a fourteen question validated survey of engagement that included questions such as:

1. How often have you worked with other students?
2. How frequently do you ask questions in class?
3. To what extend has this course emphasized mental activities such as analysis, synthesis, and thinking critically (Ahlfeldt et al. 2005)?

Questions on the survey were originally borrowed from the National Survey of Student Engagement (NSSE). The NSSE, administered nation-wide, was developed to assess student engagement in relation to the practices and conditions described by Chickering and Gamson’s Seven Principles for Good Practice in Undergraduate Education. It included a vast number of items related to the amount of time and effort students put into their studies and other educationally relevant activities (Kuh 2001, Kuh 2003).

In my study, survey results indicated that despite including a number of active learning exercises, students were not nearly as engaged as I thought they were. When compared to results of the National Survey of Student Engagement (NSSE), students in my courses were simply “on par” with peers at the national level (Hopper 2016). In this study, I also observed that student engagement scores of students in introductory anatomy and physiology did not differ from students enrolled in an upper division animal physiology course. This finding was surprising as anatomy and physiology students rely much more heavily on lower order skills (memorization) than the animal physiology students who participated in inquiry based labs and writing of lab reports. It was clear to me that a “paradox of change without difference” occurred in my teaching, and I wondered if others encountered similar conditions.

Faced with a lack of evidence that what I was doing fulfilled my objective to develop a more engaged learner, I initiated and led a faculty learning community focused on student engagement. Involvement in this community heavily influenced a course I was developing at the time. The new course was an advanced human physiology course to be offered to junior and senior level biology majors. This course was developed in response to numerous student requests for courses that would help them develop higher order skills necessary to perform well on future entrance exams such as the MCAT, DAT, and GRE. Reading and discussion within the learning community empowered me to totally rethink the way I would deliver this course, and I established two primary objectives:

1. To create an optimal and safe learning environment where the learner would be motivated to take command of their learning.
2. To include a variety of “active learning” exercises that would challenge and engage students in the work of thinking, communicating, and collaborating.

This literature based course relied heavily on a discussion based format and included a variety of active learning exercises asking students to critique, synthesize, evaluate, integrate and reflect upon what they were learning. Although students were at first reticent, by the end of the course student comments were overwhelmingly positive.
“After taking this course I feel like a more confident speaker, thinker, and I am much better at discussing and conveying my thoughts.”

“This class allowed me to gain confidence in my ability to answer my own questions. I have learned to think more critically.”

Near the end of the course, I administered the Ahlfeldt survey of student engagement. I found that students in this course were significantly more engaged in their studies than any of the other courses I had previously surveyed (Figure 1). The advanced physiology course is an example of how feedback from prior studies led me to more carefully plan a course that would be successful in achieving higher levels of student engagement. However, at the conclusion of the course, I had to ask: Did students in the advanced physiology course learn more? Did students retain information longer? Did students develop skills they did not possess before participating in the course? Clearly, the methodologies used in the course influenced student’s perceived learning and skill development, but this study lacked an objective measure of content mastery or skill development.

Although it is often thought that active learning promotes the development of Bloom’s higher order skills, at this point I had little evidence. Over 25 years ago, Bonwell and Eison published that active learning promotes development of higher order skills including synthesis, analysis, evaluation, and critical thinking (Bonwell and Eison 1991). Since that time, there has been limited published evidence to support this claim. However, the Wabash National Study of Liberal Arts Education, a comprehensive, multi-institutional study did provide evidence of positive connections between student self-reports of engagement and learning (Blaich 2011). A pretest/posttest design on six broad outcomes, including critical thinking, problem solving, inclination to inquire and orientation toward lifelong learning, were all related to measures of engagement. Although this study directly linked student engagement with improved learning outcomes, the methods used were not practical for everyday use in the classroom, as students were required to complete over four hours of assessment. The challenge remained for me (and others) to find an effective and manageable tool to assess the relationship between student engagement and knowledge acquisition.

As I transitioned from undergraduate to medical education, I once again wanted to assess the relationship between student engagement and learning. I designed a study to assess both student perceptions of engagement and proficiency in using higher order skills. Assessments included the Ahlfeldt engagement survey, and an assessment of higher order skills offered by the National Institute for Learning Outcomes Assessment. Although this assessment was originally designed for undergraduate students, the institute is currently validating its use for professional and graduate students. Choice to use this instrument was based on the fact that students could complete it in just ninety minutes, and trained evaluators scored it.

The study design compared engagement and higher order skill proficiency of students completing their medical studies in three very different campus environments. Each campus relied on varying amounts and types of active learning exercises, and ranged from nearly none to over 40% active learning. In the first year of this study (unpublished data), I found no difference in either engagement or higher order skill proficiency despite major differences in the amount and type of active learning at the three different campus sites. Although one might think that all medical students are highly engaged, and would therefore score similarly, this was not the case. Engagement scores of the medical students were lower than scores reported by students enrolled in my undergraduate advanced physiology course. These results raise additional questions: Are medical students truly less engaged? How valid is a student’s perception of engagement independent of an objective measure of their behavior? As one would likely predict, medical students did demonstrate greater proficiency in using higher order skills than senior level undergraduates (statistical analysis has not yet been completed). However, one must ask, were higher order skills prerequisite for entry to medical school, or had the skills been developed during the first year of medical studies? Perhaps most importantly, these results led to me ask:

3. Are there times when active learning does not achieve its objectives, and if so, what factors contribute?

Although the preponderance of evidence indicates that active learning is effective in achieving desirable outcomes (Dunlosky et al. 2013, Freeman et al. 2014, Froyd 2008, Michael 2006, Prince 2004, Slavich and Zimbardo 2012), there are reports in the literature to the contrary. To be clear, I believe that active learning environments are essential to skill...
development and knowledge acquisition by our students. However, not all active learning strategies are equally effective. Published reports indicate that active learning can and does fail (Ebert-May et al. 2011, Freeman et al. 2014, Miller and Metz 2014, Prince 2004). This is brought to the reader’s attention not to minimize the potential of active learning, but rather to illustrate the importance of evaluating our work in the classroom. Without evidence, we fall prey to the illusion of competence. If we are to be credible in achieving our stated outcomes, we must be willing to evaluate our work, and refine our skills and processes when outcomes do not match perceptions.

In my own work, I perceived that students were highly engaged, but student perceptions did not match mine (at least not until I made adjustments). Others have similarly reported failures in their attempts to more actively engage their students. In a twenty-two year systematic review of problem-based learning (PBL), Hartling and his collaborators report that this methodology is not unequivocally associated with enhancement of knowledge acquisition (Hartling et al. 2010). In fact, the study reports that in seven out of ten cases, students in PBL programs score lower on exams than students in traditional programs. In another study conducted in a pharmacy curriculum, “flipping” the classroom resulted in higher levels of student engagement, but lower final exam scores.

As described in a recent review of the literature, not all learning exercises are created equal, with some being more effective than others (Dunlosky et al. 2013). As we evaluate our work, and the published work of others, we must first know what we are expecting the learning exercise to achieve. Do we wish to change student perceptions, their performance on knowledge based outcomes, their proficiency in using skills such as communication, and collaboration? Perhaps it is not possible for one learning exercise to achieve all desired outcomes. Furthermore, conflicting reports in the literature describing the effectiveness of active learning strategies are likely due to a number of reasons, most of which faculty cannot fully control (Table 2). As we review the literature, and select learning activities to model, we must take into consideration many variables that impact outcomes. Each group of students differs, and there are numerous conditions within each classroom that faculty cannot control. What worked for another person, working with a specific group of students, in a specific learning environment, may not work in all conditions.

We must also remember that reports in the literature are authored by faculty who chose to develop and deliver the active learning exercise, and there may be unpublished results (grey literature) that contrast the findings. Also, when faculty are required to adopt different teaching methods, which is often the case with curricular reform, the results may vary greatly. As reported by Joel Michael, there are many reasons that faculty resist trying new teaching methods (Dunlosky et al. 2013, Michael 2007). Reasons for hesitancy in adopting new methods include factors related to the faculty member, the students, and the environment of the classroom (Table 3). Personally, I too initially experienced many reservations. However, over time, I have found that moving away from the “sage on the stage approach” has been one of the best decisions I have made as a faculty member. It is a disservice to students if we limit knowledge acquisition to what comes out of the lecturer’s mouth.

(Adapted from Michael, J. 2007 Faculty Perceptions About Barriers to Active Learning)

Table 3. Reasons faculty are hesitant to adopt new teaching methods

<table>
<thead>
<tr>
<th>Reason for Hesitancy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>How will I cover all of the necessary content?</td>
<td>Takes too much preparation time.</td>
</tr>
<tr>
<td>Takes too much preparation time.</td>
<td>Students resist non lecture environments – poor participants</td>
</tr>
<tr>
<td>Students resist non lecture environments – poor participants</td>
<td>My course evaluations will go down</td>
</tr>
<tr>
<td>My course evaluations will go down</td>
<td>My colleagues will criticize me</td>
</tr>
<tr>
<td>My colleagues will criticize me</td>
<td>It is scary – hard</td>
</tr>
<tr>
<td>It is scary – hard</td>
<td>Classrooms poorly equipped</td>
</tr>
<tr>
<td>Classrooms poorly equipped</td>
<td>Teacher has less control</td>
</tr>
<tr>
<td>Teacher has less control</td>
<td>Students lack the maturity</td>
</tr>
<tr>
<td>Students lack the maturity</td>
<td>Student assessment is difficult – hard to predict outcomes</td>
</tr>
<tr>
<td>Student assessment is difficult – hard to predict outcomes</td>
<td>Class size is an impediment</td>
</tr>
<tr>
<td>Class size is an impediment</td>
<td>Standard classroom periods are a barrier</td>
</tr>
</tbody>
</table>

Table 2. Factors that contribute to variability in published reports of active learning

- Active learning is difficult to define
- Immense diversity in types of active learning exercises
- Higher order skills – and “soft skills” are difficult to assess
- Impossible to control all variables impacting learning
- Implementations vary
- Desired outcomes vary
- Differing degrees of faculty training and “buy in”
- Different types and levels of students

Table 3. Reasons faculty are hesitant to adopt new teaching methods

Although I have been known to state, “How will I get all the content covered,” I now believe a faculty members job is not to cover all the content, but rather to find ways to engage the learner in grappling with content, and discovering for themselves how to integrate and apply concepts that are new. My shift in teaching philosophy occurred in large part as I participated in the previously mentioned faculty learning community. As I continued to seek innovative ways to meet student-learning goals, I once again turned to the literature to see what role faculty development played in the success of others.

4. Does faculty training impact the success of active learning strategies? If so, what defines “best practice” in faculty development?

To overcome challenges faculty face in adopting new teaching methods, faculty development is often provided and participation is encouraged. Although it is understandable that faculty take the “teacher as learner” approach, there are additional questions raised when considering this training. Some reports in the literature indicate that to be effective, faculty training must be intensive, sustained, and connected to performance standards (Supovitz and Turner 2000). At the other end of the spectrum, others have reported that as little as one hour of faculty training is successful in changing...
faculty effectiveness in the classroom (Desselle et al. 2012). In yet another study, appropriately titled “What we say is not what we do: effective evaluation of faculty professional development programs,” faculty who desired to create student centered classrooms were provided training (Ebert-May et al. 2011). Following the training, faculty were asked to self-report their success in achieving desired changes. Nearly ninety percent of faculty stated that they made changes in their courses that included more active and learner-centered instruction. Observational data gathered by trained observers (reviewing video tape) found that participation in professional development did not result in learner-centered teaching. The majority of faculty continued to use lecture based, teacher centered pedagogy.

In another study at a major dental school, investigators found that the majority of faculty perceive their active learning methods as effective and even report that they are more effective in using these techniques than their peers. The conundrum was that although faculty indicated that active learning was effective, most continued to rely almost exclusively on traditional didactic lecture (Miller and Metz 2014). Clearly, there is potential for disconnect between faculty perceptions and practice. Just because faculty members (including myself) incorporate active learning and perceive their course as engaging, it may not be perceived by others (students and trained observers) in the same way or at the same level. Therefore, faculty reflection upon their techniques along with assessment of student engagement and learning outcomes is necessary.

To allow me to critically evaluate both perceptions and outcomes, I have begun to consistently gather data as I develop and deliver a variety of active learning exercises. Following student exams, I mapped specific exam questions to the content of specific active learning sessions. Noting the percentage of student scoring correct answers for key concepts allowed me to evaluate which active learning sessions were most effective in solidifying student understanding. Additionally, I wrote for IRB approval and distributed a survey to gather student input (perceptions as to the effectiveness). Using a Likert scale, students responded to two or three questions asking them “This exercise enhanced my understanding of ____.” Gathering this data allowed me to evaluate perceptions of students, and at the same time evaluate a commonly utilized measure of knowledge acquisition, exam performance.

My study comparing student perceptions and exam performance is just one approach that faculty might use in determining effectiveness of teaching methods. A full description of study design is beyond the scope of this brief article, but a brief summary of items to consider is included in Table 4. There are many ways to evaluate effectiveness of changes made in the way we teach. The important thing to keep in mind is that faculty continually practice a scholarly approach to teaching, and generate evidence that what we are doing is achieving our goals and objectives. Furthermore, as members of “academia,” it is important to share our scholarly work through publication and presentation so that others may learn from both our failures and our successes.

In summary, I would encourage others to stay abreast of current standards of performance established by accrediting bodies and individual institutions. In addressing the standards, I’ve found it helpful to embrace the “teachers as learners” approach and seek faculty development and faculty teaching communities to support my work. In writing course objectives, it is prudent to consider that examination performance, in and of itself, does not capture the full educational experience of students. Therefore, we must continue to seek creative and effective modes of evaluation for Bloom’s higher order skills, and soft skills that are important in the future success of our students. It is essential that our scholarly work includes our ability to evaluate both perception and practice. In seeking a means to publish our work, there are many options available that include blogs, teaching resource centers such as the LifeSciTRC, newsletters, websites, and more traditional venues including peer reviewed journals. It is through personal questioning of our own methods, and the methods utilized by others that we can rest assured that the experiences we offer to our students, in our classrooms, fulfill our objectives.

About the Author
Mari K. Hopper, PhD, is currently an Assistant Professor at Indiana University School of Medicine. She serves as the Director of Research, Hospital Medical Education, and other Scholarly work. Prior to this position, she taught physiology-based courses at the undergraduate level for over 20 years. She is currently on the HAPS Conference Site Selection Committee, Chair of the Chapter Advisory Committee of the American Physiological Society, and Past-President of the Indiana Physiological Society. Her research interests include both student academic engagement (active learning) and student health.

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Table 4. Considerations when designing studies to determine effectiveness of teaching methods

| SETTING | • Laboratory  
| DESIGN | • Classroom  
| • Within subjects  
| • Pre and Post studies  
| • Between subjects  
| METHODS | • Surveys- faculty and students  
| • Assessments - validated  
| • HAPS Exam  
| • Observations – videotapes, rubric scoring  
| • Quality and/or quantity of behavior  
| CONDITIONS | • Timing of Assessment: Immediate, short term, or long term  
| • With and without incentives – payment, extra credit, part of grade  

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Literature cited


Engaging Students and Simplifying Your Life By Utilizing More Features of Learning Management Systems

Julia Michelle Dais, PhD
Department of Biology, Okanagan College, 1000 KLO Rd, Kelowna, BC V1Y4X8
jdais@okanagan.bc.ca

Abstract
Learning management systems (LMS) are associated with most post-secondary institutions, but when employed by instructors they mainly serve as a way to deliver materials such as course outlines/syllabi and handouts. There are many different LMS activities to choose from to simplify aspects of instruction and increase student engagement, but figuring out which ones would help students meet learning outcomes can be very daunting and time consuming. This article presents simple ways to adapt commonly used LMS features for use in online courses as well as face-to-face, blended classes in order to help students improve their communication, organizational skills, and team work in addition to learning content. doi: 10.21692/haps.2017.020

Key Words: learning management systems, course management systems, student engagement, learning outcomes, online courses, blended courses, badges

Introduction
Learning Management Systems (LMS) or course management systems are ubiquitous in post-secondary education; they have been adopted by 92.1% of post-secondary schools in the United States (Edutechnica 2016). However, Dahlstrom et al. (2014) pointed out that LMSs are not being utilized to their full potential. Of the 58% of faculty in their comprehensive survey that reported using LMSs to provide access to syllabi and handouts, only 41% of them used more advanced features to promote interaction outside of the classroom. They also noted that faculty who incorporated more sophisticated LMS features tended to have higher student satisfaction ratings.

Although I have tried many of the sophisticated features on several different Learning Management Systems, to be honest, I find that simpler is better. Through trial and error and student feedback, I have adapted basic learning management system features for use in my online courses, as well as my face-to-face, blended classes, with the goals of increasing student-to-student interactions, allowing for quick, constructive feedback of written responses, promoting critical thinking, encouraging collaboration on assignments, and ensuring students successfully navigate through the activities.

Basic discussion forums can be adapted for a variety of purposes beyond discussion of a single topic (discussed later). Quizzes delivered through LMSs can be utilized for prior learning assessment, terminology practice prior to addressing deeper concepts, or for outcome assessment. I recommend starting small and slowly adding features as your course progresses. You might wish to start by identifying a problem and then finding an appropriate LMS solution. Here are some of the hurdles my anatomy and physiology students and I have faced followed by LMS solutions that seem to work.

Problem: Some students are resistant to using learning management systems
Solution: I have found that to obtain student buy-in there needs to be a significant number of marks allotted to LMS participation. I allot ten percent of the overall weight in the course to participation in the LMS activities (LMS quiz grades are in addition to this). Additionally, making time at the end of class for one-on-one instruction on how to use the LMS is important as reluctant students may take a few weeks to finally recognize its value to their learning.

Problem: Some students miss the all-important first day of class
Solution: Learning management systems are a great way for students to access informative videos. Since anatomy and physiology is a first year course and it may be a student’s first post-secondary experience, I always create a new course introduction video each semester which explains many aspects of the course: how challenging it is, an explanation of the course outline/syllabus, and a demonstration on how...
the learning management system will be utilized. Students must watch the video to earn LMS participation marks. I post the introductory video in advance of the first day of class and send an email invitation through the LMS system. The anxious students really appreciate this. During the first class I remind students to view the video and if students have questions down the road that are addressed in the video, I can refer them back to it. I also know that students registering late to the course will be able to view this video and receive the necessary information for the course. The most important step to ensure that students have actually paid attention to the information in the video is to create an introductory video/course outline quiz on the LMS. Students repeat this quiz until they earn a score of 100% which results in earning the participation marks for this activity. Note that there are many free and easy to use screen capture programs available on line that you can search for.

**Problem: Some students have difficulty staying on track and completing activities and quizzes**

**Solution 1:** This is definitely a problem with online courses, especially if they are self-paced. Even my blended learning students (who I see twice per week) end up forgetting to complete assignments and quizzes. To help them develop organizational skills I place activity completion and activity restriction requirements on almost all LMS participation activities and quizzes. A typical LMS topic (or module) would be laid out as follows: the student would be required to download the content document (PowerPoint or Word document), complete a pre-quiz, and post to several forums before they can write the post-quiz to demonstrate what they have learned. Activity completion settings would be placed on all of the requirements for the post-quiz and the activity restrictions placed on the post-quiz itself. The LMS would then indicate to the student that the post-quiz will not become available until the listed required activities were complete. To compel online students to work their way through the course in a particular order, the pre-quiz for the subsequent topic could be set to only open when the post-quiz for the previous topic has been completed. I have designed an entire 14-week, online anatomy and physiology course for practical nursing using this approach. This allows for more student-student interactions (albeit asynchronously) even though they are progressing through the course at their own pace. Prior to this arrangement, students skipped over topics, missed important concepts needed down the road, and lost the opportunity to interact with their peers. Student feedback indicates that this approach really helps the students stay on track and increases student engagement.

**Solution 2:** Although most LMSs have features, such as boxes and check marks to indicate that activities have been completed, this still doesn’t reassure some students. I have found that badges earned for completing certain requirements can be used within LMSs. Badges are colorful images awarded upon completion of specific activities within online courses. They can be emailed to the recipient and/or set up to automatically appear within the course. Badges with titles can be created using a number of freely available, online badge-making tools. I usually link a badge to completion of the various post-quizzes associated with a specific exam, i.e. a badge entitled Exam 1 Readiness Badge would be linked to completion of post-quizzes 1-5.

**Problem: Many students haven’t learned how to come prepared to class or work in collaboration with others**

My face-to-face classes involve a blended learning approach. You could also describe my approach to teaching as a “flipped classroom” involving team-based learning. Needless to say at the start of a new semester, there is student resistance to my approach in the classroom on top of resistance to using a learning management system.

**Solution:** The preparation in advance of my classes requires students to work in teams to complete definitions of terms and take notes of learning objectives (derived from the HAPS Learning Outcomes). Over the years the students themselves have moved towards using cloud-based collaboration websites such as Google Docs to create their group notes. There is an entire aspect to this team work involving team contracts, determination of group study times, booking study rooms, sharing the load, picking up extra work to help teammates in trouble, and especially learning to deal with difficult people. Groups are responsible for accuracy of the information and I check for completion. This group assignment is submitted by posting the link for the document to an LMS discussion forum. This allows everyone in the group, as well as the class, to access the document and see the slightly different responses for terms and learning objectives. This is one way I try to help the anxious students move away from straight memorization.

When the students come to the first class on the topic, they participate in group learning activities based on the material they prepared. I wander through the room checking in on the groups, clearing up any misconceptions, and interrupting the class periodically to give mini-lectures on especially challenging concepts. The most amazing outcome of this approach is that by the final exam, no one comes to see me during office hours. I receive just a few emails from team leaders and phone calls from teams while they are together in their study groups (often in noisy coffee shops!). They have learned how to learn and carry this over to our second year courses.
Problem: Students consistently request more multiple-choice questions for practice
Solution: Multiple-choice questions on exams are a great source of stress for students. They only make up about 50% of my exams, but students always want more for practice. An activity the students and I have found quite valuable is the posting to a discussion forum of multiple-choice questions for each other to practice answering. I spend time teaching them how to design multiple-choice questions and as they practice writing the questions, they become better at answering them on exams. Of course I have to devote a bit of time to teaching the design of a question as well as giving opportunities during class time for them to practice and receive constructive feedback, but this pays off down the road. I set completion requirements for this activity; each student must separately post two questions (without posting answers) and reply with the answers to four questions. In addition to the usual LMS activity participation marks, I promise to use some of the good questions on future quizzes and exams. The instructor needs time to edit the questions, but the prospective use of these questions on tests is the main motivator for the students so this is well worth the effort. (Note: there is a free app for this type of activity that you can find online or email me for the link!)

Problem: How can we provide an opportunity for constructive feedback of written responses requiring critical thinking that students will read?
Solution: Promoting critical thinking in online courses can be a challenge, but students do love to search for information (good and bad) on the web. I use a discussion forum to ask students to find videos or animations that enhance their learning of a concept. They have to find a unique resource, post its link to the discussion forum, and provide a short, well-constructed summary to convince their peers to view it. The activity also requires that students view at least two other posts and respond with thoughtful comments to each. The activity explanation block encourages students to determine if the source is reliable, the information accurate, the video/animation engaging, and the level of content appropriate to the course. Again, I check in on these activities periodically and comment, especially early on in the semester. Interestingly, as they are writing for their peers (not for the instructor), it seems as though they put more thought into this assignment.

Problem: Plagiarism is common as students feel they need to memorize to earn high marks
Solution 1: I previously alluded to the perceived need for many students in anatomy and physiology classes to memorize content from the textbooks and notes probably in order to achieve high scores. I encourage reframing written responses as though the student were communicating with a patient or their family. The student would need to explain all of the “big words” clearly to ensure understanding. I can easily work on this with my face-to-face students, but it is a different matter with online courses. Each of my online exams includes learning objective questions that require written answers that need to be graded by the instructor. To help the grader identify plagiarism (and memorization of bullet points, a common pattern), I copy and paste the specific sections from the PowerPoints provided to the students in the grader’s area of the LMS quiz.

Solution 2: Students also have to provide an essay for the final exam. The topic changes every year and includes a personal reflection component. But to ensure students have not lifted information from other sources, I use LMS built-in software to check for plagiarism in assignments. I often set up the assignment so as to give students the opportunity to re-submit their essay after checking for and subsequently correcting “similarities” to other online sources. Students are informed that if the similarity is 25% or greater they will earn a mark of zero.

Are you ready to try something new with your learning management system? There are lots of resources online to help you no matter which system you use. Remember to start with something simple, check in with your students for feedback, and be willing to modify the activity or abandon it in favor of something different.

About the Author
Julie has been teaching anatomy and physiology, along with other first and second year biology courses, for over 30 years. That is a long time! So to spice things up she likes to “play” with educational technology and this has reinvigorated her teaching. After attending a number of HAPS conferences Julie has decided to come out of the shadows to serve on the HAPS-Blog Committee. Outside of teaching, she is involved in massage therapy research as well as enjoying life living on a lake (near a ski hill) in the Okanagan Valley of British Columbia.

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Eighty Students, Five Cadavers, and Two Professors: Innovative Teaching Practices in an Undergraduate Human Gross Anatomy Course

Elisa M. Konieczko, PhD\(^1\) and Catherine E. Mattinson, PhD\(^2\)

\(^1\)Gannon University, Zurn 203, 109 University Square, Erie, PA 16541
\(^2\)Gannon University, Zurn 211, 109 University Square, Erie, PA 16541
konieczk001@gannon.edu, mattinso001@gannon.edu

Abstract

It is becoming common for undergraduate institutions to offer cadaver-based anatomy courses to support health professions programs. Gannon University has offered cadaver-based anatomy courses for over thirty years. Human Gross Anatomy lecture and laboratory are team-taught courses that deliver a high volume of material in one semester. Formal lab experiences involve innovative pedagogical practices and cooperative peer to peer learning, while instructors and teaching assistants (TAs) direct and facilitate learning. An informal assessment of student learning occurs through a game–like experience during each lab. Supplemental instruction by the TAs gives them an experiential learning opportunity. Saturday lab practicals and a lab practical scheduled during finals week allow all students in the course to be tested on the same day creating more instructional time during the week and eliminating communication about the test among students. This format has its challenges but they are surmountable and the potential benefits to students are clear. doi: 10.21692/haps.2017.021

Key Words: undergraduate gross anatomy, pedagogical practices

Introduction

It is becoming more and more common for primarily undergraduate institutions (PUI) to offer cadaver-based anatomy courses to support programs with students majoring in physician assistant studies, pre-physical therapy, pre-medical, or other health occupation majors (Fernandes et al. 2015, Johnson et al. 2012, Kawashiro et al. 2009). While some of these students will go on to matriculate at graduate or professional schools following their undergraduate experience and take cadaver-based anatomy a second time, a significant population of students will only be exposed to cadaver-based anatomy during their undergraduate career.

The approach to teaching anatomy has changed over the years, from a purely lecture-based format to one that is much more inclusive of active learning techniques (Drake 2014, Johnson et al. 2012, Spudich and Stanford 2013, Sugand et al. 2010). Active learning has been shown to be very effective in teaching college and medical students complex scientific and medical information (King 1993, Leonard 2000, Minhas et al. 2012). Significant changes have occurred within anatomical education at the medical school level, including the movement away from stand-alone anatomy lecture and lab towards problem- and/or team-based approaches where anatomy is part of a multidisciplinary learning experience (Drake 2014, Johnson et al. 2012).

Gannon University has offered two cadaver-based anatomy courses for over thirty years. Human Gross Anatomy (BIOL 365) and Human Gross Anatomy Lab (BIOL 366) are lecture and lab courses, respectively, that are team-taught and use an experiential, cooperative learning format to deliver a high volume of complex material in one semester. This paper describes how two full time faculty members within the biology department are able to provide an effective, hands-on, experiential course that encompasses the best active learning and teaching practices for teaching cadaver-based anatomy to undergraduate students. Additionally, this article will describe the challenges, benefits, and practical aspects for implementing these techniques in such a course at PUIs and larger undergraduate institutions.

Course Descriptions and Faculty Workload

BIOL 365 is a three-credit lecture course taken by senior pre-med majors, junior pre-physical therapy majors, and sophomore physician assistant majors. The course is taught using a regional approach and is divided into four units: thorax and abdomen, head and neck, back and upper extremity, and pelvis, perineum and lower extremity. Material covered is based on the Anatomy Society core regional syllabus (Smith et al. 2014, Smith et al. 2016a, Smith et al. 2016b). The course includes a cadaver blessing at the start of the semester and an end of semester cadaver memorial service (Tschering and Reinhard 2011). Given that the average age of our students is twenty, the former helps students get acclimated to the cadavers before the start of dissection and the latter helps to remind students that the material they have spent the semester learning was due to the generosity of our donors.

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Gannon University prides itself on offering small class sizes. Thus, these courses are capped at 40 students per section. We typically offer two sections of BIOL 365 during the fall and spring semesters. Both instructors teach both sections. However, by the end of the semester, each instructor has taught one-half of the course material. Comments from end-of-course student evaluations revealed that students did not like switching instructors at mid-semester (data is anecdotal from course evaluations and is not presented in this article), so one instructor teaches the first and third units to both sections, while the other instructor teaches the second and fourth units to both sections. This arrangement has the added benefit of giving the instructors more blocks of time in which to pursue scholarly activities during the units that they are not teaching.

BIOL 366 is a one-credit laboratory course that accompanies BIOL 365. Students must take both lecture and laboratory courses simultaneously. If they want to drop out of lecture, they must also drop out of lab. BIOL 366 is a cadaver-based dissection course, in which the entire human body is dissected, from head to toe and from skin to bone, in 16 weeks. At Gannon University, each BIOL 366 section is capped at twenty students, allowing the instructor to interact frequently with all enrolled students and to ensure student safety. The instructor teaching the lecture unit also teaches the lab sections for that unit. This ensures that the students hear a consistent message for the entire unit and allows the unit instructor to keep both class and lab on the same topic.

Typically, we have one cadaver for each section of BIOL 366, plus an additional cadaver that is prosected by the instructors and the teaching assistants (TAs). We employ one TA for each lab section, plus an additional TA who is not assigned to any section. The TAs responsibilities include prosection of one cadaver, setting up and taking down materials for the weekly labs, helping to prepare and grade the lab practicals, and leading a supplemental instruction “open lab” (see below) (Duran et al. 2012).

Students in each section of BIOL 366 are divided into groups of three to four students. Each group dissects for approximately one half hour on the lab’s cadaver, and then rotates to simply review structures on the cadavers dissected by other sections of BIOL 366 (Marshak et al. 2015). In addition to the cadavers, other lab course materials include anatomical models, bones, and medical films (X-rays, CT scans, and MRI films) (Kang et al. 2012).

Supplemental Instruction

Supplemental instruction is designed to support students in a specific course. Oftentimes, courses that have a supplemental instruction component are rigorous courses that are required for health science programs. The support provided by supplemental instruction can be directly related to learning course material, but it can also help by teaching important study skills (Bruno et al. 2015).

We offer supplemental instruction in the form of open labs. The one-hour open labs serve as study hall periods with the cadavers. Open labs are hosted by TAs, who are responsible for managing the lab during these times as well as answering student questions about anatomical concepts. Open labs are also an opportunity for students to ask TAs for study tips. All TAs had to earn at least a “B” or better in BIOL 365 and 366 in order to be considered for the position. Without an instructor present, some students find it easier to ask questions because they feel the TA, as a peer, is a more approachable resource. For the TAs, their work serves as experiential learning, in that they have to keep their anatomical knowledge up to date and be able to explain structures and relationships to the enrolled students.

Participation in open labs is completely voluntary, but it is strongly recommended by instructors. Students may attend up to five open labs per week. Open lab attendance is always highest during the week prior to an exam. We believe that supplemental instruction in the form of open labs is absolutely essential for students to do well in our course. Scheduled lab periods are only three hours per week, and in order to learn human anatomy thoroughly, students need the extra time and support provided by supplemental instruction.

Peer-to-Peer Cooperative Learning

In BIOL 365, course instructors use lectures, threaded with some active learning techniques, to introduce and explain complex anatomical structures and arrangements. Students are strongly encouraged to form “study-buddy” groups to understand and master the material from both the lecture and the lab courses. Reading the text and memorizing anatomical facts are best accomplished by independent work. However, the study-buddy groups serve as peer-to-peer learning forums in which students quiz each other using a few multiple choice questions provided by course instructors. “Quick quizzes” test explicit facts that students are required to learn and “application quizzes” require students to apply material to solve clinically-based questions. Students also use questions that they themselves develop (Whelan et al. 2015). For lecture students are encouraged to take turns explaining the material, asking questions of other students, and answering questions posed by other students. These activities often help our students discover deficiencies in their learning, which they can correct prior to an exam.
During scheduled lab periods students dissect their cadaver in groups of three or four. These groups are assigned randomly and are changed for each unit in the course. Each group dissects for approximately 30 minutes in the three-hour lab period. The instructors and the TAs help students with their dissection techniques, especially in the first few weeks of the course (Lamdin et al. 2012). Three members of the group perform the dissection, while one member, the “reader”, reads from the course dissector and refers to structures in an atlas. At the end of their group’s dissection period, the reader is required to make a presentation to the next lab group, informing the next group about the dissection that has just been completed. Thus, the students are constantly required to recap to their peers the dissection instructions, region-specific anatomical structures revealed partially or entirely during the dissection, and any anomalies they may have encountered.

In the open lab sessions, the study-buddy groups are encouraged to employ reciprocal peer teaching (RPT), in which students alternate teaching material to their peers and learning from their peers within their study-buddy group. When the RPT technique has been used in medical school anatomy labs, it has been shown to improve student learning and retention of material (Krych et al. 2005, Manyama et al. 2016). Our student groups typically come into the lab with a short list of structures to identify on each of the cadavers. Each student within the group is responsible for five to ten of the list structures that they need to be able to show their group members. Students begin on one cadaver and try to find the structures on that cadaver. Once the structures are identified, the group moves on to the next cadaver. By the time the group has identified the short list of structures on all of the cadavers, they have learned not just the structures, but the anatomical relations of the organs as well. The RPT method allows students to work cooperatively to learn the necessary material, and helps students to build confidence in their knowledge base as well as their communication skills. Applying RPT across multiple cadavers gives students the opportunity to understand and appreciate the inherent variations that exist in structures through direct comparisons from cadaver to cadaver. As an added way to supplement their studying, the students often quiz each other about the anatomical facts of the organs (i.e., innervations, blood supply, and muscle origins and insertions) during these in-lab sessions. One added benefit of the students’ participation in study-buddy groups, RPT, and the supplemental instruction is the unification of the class as a whole. Comments from student evaluations and the memorial service at the end of the course reveal that friendships have formed between students of different majors and with those students outside of their social circles (data is anecdotal from course evaluations and is not presented in this article).

Informal In-class Assessment

Anatomy courses require students to learn large volumes of material quickly in order to cover the entire human body in one semester. If a student is struggling with material or not using effective study habits, the student can quickly fall behind to the point where they simply cannot be successful in the course. Instructor identification of struggling students can potentially be used to try to prevent this from occurring (O’Neill et al. 2016). As a proactive approach, we use an informal in-class assessment in our scheduled lab periods to gauge student learning. This assessment is a game-like activity entitled “Pass the Probe” and it allows instructors to reinforce correct naming of structures, as well as answer student questions.

The game is played within small groups after the students have had time to review material on our prosected cadaver. In the last five minutes of the student group’s rotation at the prosected station, the instructor approaches the tank, and whoever is holding the group’s probe is responsible for starting the game. When a student is holding the probe, they either have to identify a structure or ask a question. If the student chooses to identify a structure, they are expected to state the side orientation of the structure if appropriate (e.g. left or right), state the proper name of the structure (e.g. pectoralis major, ascending cervical), and then state the type of structure that is being identified (e.g. vein, artery, nerve, muscle), as they are expected to do on lab practical exams. Alternatively, the student can ask a question of the instructor if they need clarification. Once the student has either correctly identified a structure or received an answer to their question, they pass the probe to the next student in their group. The probe is passed from student to student for five minutes, at which time the assessment is concluded and the group rotates to the next lab station.

The purpose of this exercise is to quickly assess student learning and reinforce the use of proper anatomical terminology. It also controls for students who do not like to talk and those who want to ask a lot of questions. As each student must take a turn with the probe, even quiet or shy students identify structures or ask questions, building their confidence and helping them to find their voice in lab. Moreover, students who tend to ask a lot of questions do all of the answering for the group can only point out one structure or ask one questions. This lets all students in the group participate. Additionally, students observe the identifications and questions made by their peers, thus potentially increasing their own learning (Pratten et al. 2014). The assessment is not graded, so students do not feel the pressure to have perfect answers to earn points. However, the student’s choice of structures to identify or questions to ask can provide a good deal of insight into how the student is progressing prior to a lab practical exam. If the instructor
feels that a student is not performing as they should, the instructor can intervene by requesting to meet with the student well in advance of an exam to suggest ways to improve studying.

**Saturday Lab Practicals**

In many undergraduate institutions, where multiple lab sections of the same course are offered at different times and on different dates, instructors have two options: they can use one version of an exam and hope that students maintain the academic integrity of the exam by not discussing it with their peers or they can create multiple versions of the same exam. The former option is less time consuming but it unlikely that all students who take the exam will keep its content confidential. The latter option minimizes cheating but it can be very time consuming. An ideal solution would be to test all students at the same time on the same day. In pursuit of this ideal, our course has implemented Saturday lab practicals. The practical exam itself is structured to be completed in one hour; students answer 80 questions distributed over 40 stations. In addition, five “rest” stations are interspersed among the questions stations to allow students to complete answers and regroup before the next round of questions.

Obviously, there are issues that arise with Saturday lab practicals. In the event that a student cannot make an exam for a prior personal commitment or another university event occurring on the same day, we offer an oral make up exam the following week. However, this policy has now been in place long enough that most students know that Saturday exams three times during the course of the semester are to be expected.

There are several benefits associated with Saturday lab practicals. With all of the students from all of the sections taking the exam at the same time on the same day, there is no opportunity for students to share exam content with others who have not taken the exam yet, thus maintaining the integrity of the exam. Students who require additional time for exams, due to learning disabilities or medical conditions, can take different sets of electives before anatomy.

This allows grades to be posted to the university course management system very quickly, providing students with prompt feedback.

Saturday exams also allow instructors to use all scheduled lab time to teach or review material; no time is taken away by testing. As an example, we usually allot three weeks to cover thorax and abdomen in lab followed by one week of review. If Saturday exams were not feasible, we would lose a review week to the detriment of our students’ preparation. The advent of Saturday exams allows us to balance the rigorous material that we need to cover with the time necessary for our students to learn it.

**Challenges**

In medical school, there is only one population of students enrolled and all enrolled students take exactly the same schedule. In undergraduate anatomy classes, especially at small or medium size PUIs, several different populations of students are enrolled in the same anatomy class. All students must meet course pre-requisite; however, different majors take different sets of electives before anatomy.

Additionally, unlike medical students, college undergraduates must take several other courses along with anatomy to stay on pace for graduation. Undergraduate lecture courses are usually three credits meeting three hours over the course of a week. Undergraduate students often earn only one credit hour for an afternoon lab 3 hours in length. Thus undergraduate students are typically in anatomy lecture and lab for a total of 6 hours per week. In contrast, medical students typically take anatomy as a block without any other course or, if they are engaged with problem-based learning, they may have multiple hours per week dedicated to anatomy.

Another challenge we have encountered, especially with sophomore level students, is the lack of previous exposure to high-volume, high-intensity courses. This is often not a problem for senior level students who have previously taken Organic Chemistry I and II, Calculus, Physics I and II, as well as demanding upper level biology and chemistry courses. However, sophomore and junior level students often struggle with the study pace of anatomy (Elizondo-Omana et al. 2006). Moreover, many undergraduates, even senior level students, may have very poor study and time management skills. Comments from student course evaluations reveal that these courses have taught them how to study (data is anecdotal from course evaluations and is not presented in this article).

Finally, an additional challenge at undergraduate institutions is the lack of faculty to teach cadaver based anatomy. In medical schools, there are often several faculty members

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who teach anatomy while working under a course director. This is especially true at schools using problem-based learning, where the discipline of anatomy is combined with other disciplines. At the undergraduate level, anatomy is its own discipline and is not integrated into other courses. In addition, many undergraduate institutions employ only one faculty member to teach all anatomy classes and labs, which can lead to faculty burnout.

Benefits
Just as many high school students take Advanced Placement or other college level classes to prepare themselves for college work, many college undergraduates take upper level electives such as biochemistry, histology, embryology or comparative anatomy to prepare for medical or graduate school. Studies have shown that students who take cadaver-based anatomy as undergraduates are better prepared for graduate work (Forister et al. 2002, Peterson and Tucker 2005). Increasingly, PUIs are offering programs in physician assistant science, athletic training, or sports and exercise science in which students do not go on to graduate programs, but obtain employment following graduation from their undergraduate institution. For those students, their only exposure to anatomy will be in an undergraduate course. Additionally, at the undergraduate level, anatomy is its own discipline and is not integrated into other courses. This allows students to focus on gaining a deeper understanding of anatomy.

Most undergraduate institutions have significantly smaller class sizes than medical schools allowing students more access to instructors. This improves student study and time management skills. If the institution is able to employ a team of two or three faculty members to teach anatomy, workload can be spread among instructors. Team teaching as we do it at Gannon, where students learn lecture and lab information from one instructor per exam section, means a consistent message is given to students and instructors are given larger blocks of time for scholarship when they are not teaching a section. One important factor in the success of team taught courses is communication between the two faculty members. Students will occasionally try to manipulate one faculty member against the other in asking for points back on exams or in making excuses for missing assignments. Copying each other on all emails to students and administrators ensures that both faculty are in the loop and able to respond to all situations. Weekly meetings with each other and with TAs, as well as offering a couple of office hours at the same time each week can also help to ensure course success.

Conclusions
Many undergraduate institutions are now offering programs in health professions. These programs prepare students for employment in the health care fields immediately following completion of an undergraduate or master’s degree. Such institutions are increasingly offering cadaver-based human gross anatomy to support these programs. This can be a huge challenge for an undergraduate institution. Gannon University has successfully offered these courses for over 30 years. As described above, it is possible to offer high quality, innovative cadaver-based human gross anatomy lecture and lab, stressing communication between the two faculty members, small class size, supplemental instruction and Saturday examinations. We believe this method of teaching cadaver-based anatomy can be a model for other undergraduate institutions.

About the Authors
Elisa M. Konieczko PhD is a Professor at Gannon University. She is a member of the American Association of Anatomists and the American Association for Cell Biology. She primarily teaches undergraduate human gross anatomy courses, but she has also taught cell biology lecture and lab courses.

Catherine E. Mattinson PhD is a former Assistant Professor at Gannon University where she taught undergraduate human gross anatomy courses to pre-health professions students and human anatomy and physiology courses to allied health professions students. She is a member of the HAPS Cadaver Use Committee. She recently relocated to Ohio with her family.

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Literature cited


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Literature cited


Establishment of an Interactive Community Outreach program in Human Anatomy and Physiology: The HAPI Lab Model

Bridgett R Severt MS, Barbara Kraszpulska PhD, and Thomas L. Brown PhD

Department of Neuroscience, Cell Biology, and Physiology, Wright State University Boonshoft School of Medicine, 3640 Colonel Glenn Hwy, 105B White Hall, Dayton, Ohio 45435
bridgett.severt@wright.edu, barbara.kraszpulska@wright.edu, thomas.L.brown@wright.edu

Abstract

Educational institutions, high schools, technical schools and colleges, look for innovative ways to enhance student knowledge and understanding of human anatomy and physiology by finding novel, interactive methods to facilitate the learning of critical concepts. At Wright State University, we have developed a self-sustaining, community outreach program to introduce students to a cadaver lab in order to enhance their knowledge of anatomical and physiological principles. We developed the Human Anatomy and Physiology Interactive Lab (HAPI) program specifically to engage anatomy and physiology students. It is our hope that the program described in this article may serve as a model that can be used to replicate the success we have observed. This article addresses the application process, logistics, implications and legal considerations for the HAPI Lab program.

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Key Words: anatomy and physiology, laboratory, outreach, cadaver lab, educational, interactive

Introduction

Scientists and educators may get involved in community outreach as a way to communicate complex technical information in an easily understandable way (Bubela 2009, Brownell 2013, Komoroske 2015). The interactive component of community outreach programs promotes a high level of enthusiasm and excitement in student learners and increases the level of concept retention (Luckie 2012). Community outreach programs may also provide new student motivation or trigger the spark that leads students in new directions (Devonshire 2014). Verbal and written feedback from students and teachers clearly indicates that university outreach efforts have a positive and long-lasting impact on young people (Anderson 2011).

Exposure to human anatomy and physiology is a critical part of science education that helps prepare students for pre-professional programs (Clark 2016). Recent studies support the belief that anatomy and physiology education can be enhanced by providing outreach activities that allow participants to understand the subject matter and its applications more thoroughly and to develop valuable communication and interpersonal skills (Baram-Tsabari 2015). Overall, community outreach programs promote a highly effective learning environment by providing a critical bridge between the public, students, and academia. In such an environment deeper understanding of concepts is possible, misconceptions can be addressed and intimidation of the subject matter can be reduced.

The outreach activity described in this article is designed to enhance the learning outcomes of anatomy and physiology students from area educational institutions who visit Wright State University for a 90-minute interactive laboratory experience. The Wright State University Anatomical Gift Program provided institutional approval for this interactive outreach activity.

Learning Objective/Outcomes

Learning objectives for the HAPI Lab program were adapted from the HAPS Learning Goals for Students. We expect students to have a basic understanding of the human body when they arrive for HAPI Lab. By the end of our 90-minute session, we expect the students to be able to:

- Recognize major human anatomical structures and organs
- Explain the basic physiological functions of organs and organ systems in the human body.
- Recognize organs in normal and diseased states.
- Integrate ideas to make connections between anatomical and physiological functions and real-world situations, promoting a healthy lifestyle.
- Understand the effects of homeostatic imbalance

Exposure and Promotion

A visually eye-catching group photo of faculty and graduate teaching helps to explain what the program is about (Figure 1). This photo also serves as a vehicle for program promotion in the news, social media and program announcements.

Figure 1: Programmatic photo for advertising, news media, and announcements. Program coordinators and graduate teaching assistants involved in HAPI Lab outreach are photographed to provide a visually catching idea of what the program is likely to be about.
Reservations and Communication

Due to lab space constraints, a maximum of 30 students are accepted for each HAPI lab session. All lab presentations are offered on Friday from 10:30 am to 12:00 pm during the Spring Academic Semester. We adopted this time period because by the spring semester educators have had the time to introduce their students to anatomy and physiology and to cover the organ systems that the students will see in the HAPI Lab. Reservations are made by officials of potentially participating schools via email to provide a time stamp and proof of communication. We accept initial reservations on a first come, first served basis, on the third Monday in October for the following Spring Academic Semester. The program is popular, with some potential participants emailing at 12:01 am the day the reservations open. Subsequent communications between participant school officials and HAPI Lab personnel document the number of students who will participate in the HAPI Lab program, the prerequisite courses the students have taken to prepare for the program, and the preferred dates of attendance. One week prior to the scheduled visitation, participating teachers are sent a confirmation email, which includes a detailed description of the HAPI Lab program, parking directions, and a waiver form to be signed by the each student’s guardian.

Arrival and Orientation

Upon arrival, a participant-arranged bus drops the students off at the entrance of Wright State University’s Boonshoft School of Medicine. The group is assembled in the atrium where they are supervised by as many as three graduate teaching assistants and at least one program coordinator, all of whom are present at all times during the visit. A group photo is taken so the participating school can include it in their school newsletter and the photo is posted on the HAPI Lab website (Figure 2). The program coordinators and the graduate teaching assistants (GTAs) are introduced to the group and the lab rules and expectations are explained to the students. Explanations cover the anatomical gift program, the importance of respect for the donors, and what to do if a student is uncomfortable or feels that he/she may pass out. Students then put their belongings in lockers and enter the lab where they are divided into five groups and seated at pre-prepared tables.

Group Division and Activities

The HAPI lab session begins with an oral activity in which each group of students attempts to name the eleven organ systems. Once students are confident with their list, they go around the room naming one organ system at a time. As each group calls out the name of an organ system, GTAs provide them with a laminated card imprinted with the name of the system they called. This activity adds an interactive aspect to the lab and provides a level of comfort for the participants.

Figure 3 Matching Game: functions of systems and organs. The students work in groups to find the card with the function that matches their previously selected organ system (a). Students then match the organs (b) with their organ systems. We discuss the functions of the systems and the organs that belong to each system as a class once students have found their matches. This figure shows a small sample of the organs cards.

Upon completion of this activity, discussion of the function of each organ system begins. A matching activity is set up at a staging table in the front of the room. Laminated cards are displayed on the table, each imprinted with the function of one of the organ systems (Figure 3a). One or two participants from each group come up to the staging table to find the card with the function of their system and take it back to their table. When all the functions have been coordinated with each system, a full group discussion of the systems is implemented. Diseases and disorders associated with the systems are included in the discussion to increase the level of student interaction and participation.

Figure 2: Group picture and orientation. Upon arrival, for each session and each school, a participant group photo is taken to establish the framework of the session and provide a source for websites and school newsletters.
After the discussion of the functions of the organ systems is complete there is another matching activity. For this activity, thirty cards are placed on the staging table, each imprinted with a name of a different organ (Figure 3b). One or two participants from each group come up to the staging table and try to find all of the organs that belong to their system. We then go around the room discussing the role of organs in each system: where they are located in the body, what their function is, and if we can live without the organ. We include some organs that belong to more than one system in an effort to challenge the students’ depth of understanding.

Healthy vs. Diseased Organs

After completing the matching games and discussion of the organ systems, disposable gloves are provided and the students circulate around the room to examine and handle healthy and diseased organs at six different stations (Figure 4). The first station contains human bones. The second station holds a brain and spinal cord. The third station has livers, kidneys, and spleens. The fourth station presents hearts and lungs. The fifth station has representatives of diseased organs. The sixth station shows an extraordinary dissection of the human nervous system (Figure 5). The participants have the opportunity to move at their own pace, ask questions and spend as much or as little time as they like at each station, depending on the level of student interest. The GTAs manage these stations and are available to answer questions.

Cadaver Observation and Interaction

Cadaver interaction is the last part of the HAPI lab session. The cadavers are covered until we reach this stage of the program to prevent unnecessary distraction. When we reveal the cadavers, students can observe how everything we have discussed is part of the human body (Figure 6). This experience is designed to maximize the learning opportunity by allowing students to see how the organ systems are integrated into the body as a whole. This experience is designed to leave a lasting impact and to reinforce what the students have been learning. It is like putting the pieces of a puzzle together.

**Figure 4:** Students compare healthy vs. diseased organs. The healthy organs are located in the top row, and the diseased organs are located in the bottom row. The organs evaluated were (a) comparing a healthy liver to a liver with cirrhosis, (b) comparing a healthy heart to a heart with a left ventricular assist device, (c) comparing a healthy lung to a smoker’s lung, and (d) comparing a healthy kidney to a kidney with polycystic kidney disease.

**Figure 5:** Dissection of the human nervous system. HAPI lab participants get the chance to view a remarkable dissection of the nervous system completed by our graduate and undergraduate students.

**Figure 6:** Cadaver interaction. The last interactive phase of HAPI lab is examination, evaluation, and interaction with human cadavers. The head must remain covered and all physical identifiers must be removed prior to participant viewing.
It is of critical importance to ensure that the students cannot identify the cadavers. The face remains permanently covered and any identifiers of the donors are removed. All toe tags, which must remain on the body at all times as per our agreement with Wright State University’s Anatomical Gift Program, are taped so that they cannot be read. Potentially identifying characteristics on the body, such as tattoos, are also covered. We ask the educators to inform us of any student who has a family member or family friend who has donated their body to the Wright State University’s Anatomical Gift Program in the past three years.

Final Assessment
Following the cadaver observation and interaction, student learning is assessed with a scavenger hunt. To accomplish this, students return to their original group and each group receives a binder with a list of structures to find, an atlas, and a small container with labeled pins that match the list of structures in their binder. Students are asked to use the pins to label the body parts on the cadavers. Once students have completed this task, they are asked to go around and look at all of the labeled structures and correct any mistakes they find. This final activity allows students to reach higher levels of thinking and a deeper understanding using critical analysis and evaluation as they reassess the work of their classmates as described in Blooms Taxonomy (Engelhart 1956).

Evaluations and Final Remarks
At the end of the session, students fill out an evaluation form to provide feedback about their experience and learning. They are asked if they would recommend the program to classmates. As students file into the locker room to wash up, we pass out HAPI Lab lanyards as a keepsake from the program, thank them for coming, and answer last minute questions. The school bus meets the students in front of the Boonshoft School of Medicine to take them back to the home school.

Results and Discussion
The HAPI lab program has received excellent feedback and evaluations since its inception (Figure 7). In the future, we plan to implement a new method of reserving lab dates. We will add a reservation request form to the program description and educators will submit it to us by email on the opening reservation date to simplify our communications. Due to the overwhelming response and success of the program, we will also plan to limit schools to one group per year unless we have openings at the start of the spring program. The success of our HAPI Lab Program has inspired others on campus to engage in community outreach. The HAPI Lab model has already been used on Wright State University’s campus to develop a new outreach program called Neuro Lab.

Figure 7: HAPI Lab Evaluation Data. Comparison ratings over the past three years with the y-axis rating scale as follows: 3 – excellent, 2 – somewhat, 1 – not at all. Numbers 1-5 on the x-axis refer to individual questions. (1) Was the presenter effective in explaining the human body complexity? (2) Did seeing the human cadaver benefit your understanding of anatomy and physiology? (3) Did the experience enrich your education? (4) Did the experience meet your expectations? (5) Would you recommend this program to your peers? [2015: n = 202 students], [2016: n = 229 students], [2017: n = 225 students].

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In summary, we have developed a highly successful community outreach program to promote, enrich and inform students about the anatomy and physiology of the human body. The structure and organization of the HAPI lab and the inclusion of detailed procedures provided with it will allow for rapid replication and implementation. We hope that it will serve as a national model for interactive anatomy and physiology education.

About The Authors

Bridgett Severt, MS, is a Lecturer in the Department of Neuroscience, Cell Biology, and Physiology at Wright State University. She is a co-course director for the undergraduate Anatomy and Physiology and Human Structure and Function courses serving pre-health students, nursing students, and biomedical engineering students. She also teaches gross anatomy and embryology to medical students at the Boonshoft School of Medicine. In addition to teaching, Bridgett is involved in community outreach projects such as the one described in the article.

Barbara Kraszpulska, PhD, is an Associate Professor at Wright State University. She is a course director for Human Gross Anatomy for MS Anatomy graduate students in the Department of Neuroscience, Cell Biology, and Physiology. She also teaches gross anatomy and embryology in the Human Structure course at the Boonshoft School of Medicine. In addition to teaching, Dr. Kraszpulska is interested in creation, utilization, and evaluation of computer-assisted technology applied to anatomy teaching at different levels. She is involved in community outreach projects at Wright State University.

Thomas L. Brown, PhD, is a Professor and Associate-Chair for Research at Wright State University. He teaches in the Department of Neuroscience, Cell Biology, and Physiology; Department of Obstetrics and Gynecology; College of Science and Mathematics, and the Boonshoft School of Medicine. Dr. Brown is a full member of the NIH Pregnancy and Neonatology Study Section, Center for Scientific Review. His research focuses on the underlying factors that can cause pre eclampsia and pregnancy-related disorders that lead to premature birth. He is involved in developing community outreach projects at Wright State University.

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Literature cited


Introducing Pathophysiology Models into a Large Lecture Hall: Investigation of the Effectiveness of Guided Inquiries Involving Movement Outside the Classroom and Independent Learning

Zoë Soon PhD\textsuperscript{1,4}, Melanie Robles, BHK\textsuperscript{1,4}, Stephanie McKeown PhD\textsuperscript{2,4}, and Heather Hurren MEd\textsuperscript{3,4}

\textsuperscript{1}School of Health and Exercise Sciences
\textsuperscript{2}Director, UBC Okanagan Planning and Institutional Research, Office of the Provost and Vice Principal
\textsuperscript{3}Centre for Teaching and Learning
\textsuperscript{4}University of British Columbia Okanagan, 3333 University Way, Kelowna, BC, Canada, V1V 1V7

zoeanne.soon@ubc.ca (corresponding author), melanie.anne@hotmail.com, stephanie.mckeown@ubc.ca, heather.hurren@ubc.ca

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Ethics Certification: H13-01964

Abstract

Central aspects of this study were first presented as a poster at the 2016 Human Anatomy and Physiology Society (HAPS) annual conference (May 2016). This pedagogical research study involved using plastic pathophysiology models that exhibit various diseases and disorders of interest. Hands-on activities involving these models were incorporated into a large lecture- and discussion-style third-year pathophysiology class. At the end of term, these model activities were compared to on-line quiz challenges, by gauging the levels of student enjoyment, engagement, and satisfaction with each of these activities. In addition, this study analyzed the correlation between visual, auditory, read/write, and kinesthetic learners with use of the models. doi: 10.21692/haps.2017.023

Key words: plastic models, pathophysiology, large lecture

Introduction

Previous research has shown that by using hands-on activities, student engagement and academic performance increases in comparison to strictly lecture-based instruction (Hake 1998, Prince 2004, Flexner 1910). It has also been found that anatomical models are useful tool in keeping students engaged and stimulated (Serrat \textit{et al}. 2014). In 2011, Chan and Cheng investigated the use of low-fidelity, physical models of the human body as used in teaching human anatomy published in three major journals over a ten-year period (2001-2010). These models included: body paint, muscle cut-outs for attaching to a skeleton, clay, fabric, foam, elastic hair bands. They found that there were many advantages to using such models. They served as memory aids, reduced cognitive overload, assisted problem solving, and increased student interest and engagement levels (Chan and Cheng 2011). Interestingly, Lombardi \textit{et al}. (2014) found that plastic model use correlated with higher overall scores on tests that immediately followed the lesson, as well as on tests given two months later. In fact students that used plastic models performed better on both tests, in comparison to students who had used virtual dissections or organ dissection instead of plastic models during their small group activity work.

In 2010, Gray \textit{et al}. found that low-cost models (e.g styrofoam ball and flashlight) can effectively be brought into large lecture classes and did improve student learning. In this case, Gray \textit{et al}. had students use the ball and flashlight to demonstrate the earth’s orientation in relation to the sun during each season (Gray \textit{et al}. 2010). With large lecture hall settings, one of the issues with using hands-on models is effective dispersal and retrieval of model material. As well, it is desirable to closely monitor how students interact with the model material to ensure that the interaction is efficient and accurate in promoting learning (Steer \textit{et al}. 2005).

Steer \textit{et al}. (2005) opted for a simple model (string) that could be passed out quickly, and could be utilized alongside guided inquiry questions to prompt students to utilize the string (and drawing) effectively in furthering their understanding of the solar system. In addition, teaching assistants circulated the lecture hall to answer student questions and check drawings and modeling. In 2004, Serrat \textit{et al}. delivered modules to a large human gross anatomy class at Marshall University through portable bins that could be accessed at any time. The students were able to use the self-contained modules individually or in a group as a part of a self-study format designed to enhance learning (Serrat \textit{et al}. 2004).

Although plastic organ models have been found to be mainly beneficial to students, the literature also reports a downside to using them. It is thought that the simplicity of the models means there is a possibility that they are overly simple for more upper-level courses (Lombardi \textit{et al}. 2014). Typically these models do not depict all the anatomical aspects of the actual organ (Lombardi \textit{et al}. 2014). To make up for the basic nature of plastic models, adding complex activities to the models may help in the upper level courses.
By adding the crosswords to the plastic models in our study, we added more difficulty to the simple plastic models and provided guidance and incentive to read the models’ attached information sheets. In this way, students were guided in their learning of the relevant anatomical structures, vocabulary terms, and pathology details depicted on each model. Part of the purpose of this study was to determine if students enjoyed the activity and found the models useful for their learning experience. In addition, we were interested in determining whether visual, auditory, read/write, or kinesthetic learners benefitted more from using plastic models. It was hypothesized that kinesthetic learners would enjoy and benefit the most by using plastic models.

Methods:
Consent and VARK Survey
All third-year pathophysiology students were given a chance to fill in consent forms to participate in this study. Students wrote the VARK survey (Fleming, n. d.). This survey was optional and not for marks, but was highly encouraged, with ample time for writing each during lecture time. A discussion about VARK, metacognition, and range of study tools and tips was engaged in during lecture time.

Pathophysiology Model Scavenger Hunts
In this study, four scavenger hunt activities were introduced into the course. Each scavenger hunt consisted of a plastic model depicting the pathologies of one or more ailments that was being studied in class. In addition, a crossword containing key vocabulary words for each ailment was provided as part of the challenge with relevant anatomical or pathophysiological clues. These scavenger hunt activities were optional, but were rewarded one bonus point each.

Other opportunities to earn bonus points both in and out of class were also included in the course to provide a variety of learning resources and options for the students. These other opportunities consisted of: answering questions during each class (1 point per correct answer) and answering quizzes on-line (1 point per 100% score on a quiz). To collect points, students could answer as many questions as they wanted to in class and complete as many of the on-line quizzes and scavenger hunt challenges as they chose. If a student was able to collect a maximum of ten bonus points by the last day of class, they earned a two percent bonus towards their final grade. We were interested to see which of these resources students would find valuable and whether there were any correlations between participation in pathophysiology model activity with learning style.

As such, before any plastic model locations were told to the students, students were asked to complete the VARK (Visual, Auditory, Read/Write, and Kinesthetic) survey (Fleming and Baume 2006). This survey was designed to assess the student learning style(s), specifically whether they are visual, auditory, read/write, kinesthetic, or multimodal learners. By completing these surveys, the students are able to determine their primary learning styles, gain tips on effective study strategies, and reflect in a metacognitive manner on how they currently study and learn, and on any future changes they may want to make in their study habits. In addition, survey data was used to determine what kind of learners benefited the most by using the plastic models.

The plastic models were hidden in the library so that all students had access to them at a time that was convenient for them. The university library is open seven days/week and holds long hours (Mon.-Thurs. 7am-12am; Fri. 7am-10pm; Sat. 9am-10pm; Sun 10am-12am). As well, the librarians could assist in keeping the models safe and secure. This mystery location was relayed to the students in the form of a riddle on their Blackboard Connect course website. Scavenger hunts were chosen as the means of delivery, due to the large class sizes and the fact that there was only one model for each organ available. It was thought this would be a way to give all students access to these models and allow them to spend as much time as they’d like investigating each model’s depiction of various disease states.

Another reason for the scavenger hunts, was to promote movement and exercise outside the classroom, as well as discussion amongst students about pathologies. Their instructor encouraged this strategy and it was anticipated they would likely embark on the scavenger hunt in pairs or groups. All plastic models came with a crossword that was related to specific models and required that the model be viewed to achieve 100%.

The models included in this study were the heart, lung, brain, and lumbar vertebrae pathologies models. Each model-related vocabulary crossword was available online via Blackboard Connect when the subject was being taught in lecture. Students could print them out and had several weeks to complete and hand in the crosswords. It was predicted that each crossword activity would take 30 minutes.

After the deadline, and once all the crosswords were handed in, the students were asked to complete a survey about their satisfaction with the model activities and the on-line activities. The survey was given to them after their final exam. Because this survey was for research purposes, students were able to opt out of filling out the survey and consent forms at any time. Participation and data analysis was blinded from the instructor of the course.

Results:
Student Participation
Out of the 182 students in the 2014 third-year pathophysiology course for human kinetics students, 119 students gave written consent to participate in this study. Out of those who consented, 47 participated in the heart model activity (39.50%), 29 in the lung model activity...
(24.37%), 35 in the brain model activity (29.41%), and 30 in the lumbar model activity (25.21%). Some of these students participated in more than one model challenge. In addition, 53 out of the consenting 119 students (43.7%) also completed the final satisfaction survey.

**Plastic Models and Crosswords**
In the heart model crossword, individual scores ranged from 78% to 100%, with the average score being 95.13%. In the lung model crossword, individual scores ranged from 77% to 100%, with the average score being 97.55%. In the brain model crossword, individual scores ranged from 82% to 100%, with the average score being 98.54%. In the lumbar vertebra model crossword, individual scores ranged from 79% to 100%, with the average score being 96.83%.

**Student Satisfaction Survey**
After the crosswords were completed, the students were asked to complete a survey. The survey consisted of the following statements and was measured using a 5 point Likert scale (Strongly Agree to Strongly Disagree):

**Part 1. Scavenger Hunt – Pathophysiology Model and Vocabulary Challenge Survey Questions:**
- I found looking at the plastic models useful for this course.
- Scavenger hunt crossword bonus challenges should be used again next year.
- As far as school goes, I enjoyed the scavenger hunt crossword bonus challenges.
- I found the scavenger hunt crossword bonuses useful.
- I found the scavenger hunt crosswords helped me understand class material.
- I completed the scavenger hunt crosswords with another student(s).
- The scavenger hunt crosswords led to conversations about pathophysiology topics with other students.
- I think the scavenger hunt crosswords were helpful for learning and preparing for exams.

**Part 2. On-Line Participation Bonus Challenge Quiz Survey Questions:**
- On-line participation bonus challenges should be used again next year.
- As far as school goes, I enjoyed the on-line participation bonus challenges.
- I found the on-line participation bonus challenges useful.
- I found the on-line participation bonus challenges helped me understand class material.
- I completed the on-line participation bonus challenges with another student(s).
- The on-line participation bonus challenges led to conversations about pathophysiology topics with other students.
- I think the on-line participation bonus challenges were helpful for learning and preparing for exams.

![Student Satisfaction Survey Results](continued on next page)
Overall, the majority of students enjoyed the plastic models and crosswords and found them to be beneficial to their learning experience (Figure 1). Specifically, it was found that of those students who participated in the scavenger hunt model activities, 55% of students reported that looking at the plastic models was useful for this course.

In the next set of questions, comparing whether students thought that the scavenger hunts (SH) or online quizzes (OQ) were helpful for learning and preparing for exams, 58% of students agreed that the SH activities were helpful and 68% of students agreed that the OQ activities were helpful. These positive results, with favoring of the OQ activities, were expected. Furthermore, it was anticipated that students would perceive the OQs as being the most helpful, as the questions were framed in the same style as the midterm and final exam questions (multiple choice, fill-in-the blank, matching, true/false, and short answer). In the SH activities, the crossword style clues would be helpful for learning vocabulary words as well as anatomical and physiological aspects of diseases and disorders; but were not in the same style as exam questions.

The third comparative set of questions in the survey asked the students whether each activity led to conversations about pathophysiology topics with other students. Forty-seven percent of students agreed that the SH activity led to conversations and 44% of students agreed that OQs did. We were not sure whether students would answer this question honestly, as some students may perceive that talking to each other about school work was prohibited or frowned upon. The instructor of the course had however, encouraged the students to work in pairs or groups, stating that it has been shown that discussion of schoolwork can help with learning and long-term memory. It is unclear whether or not students remembered this or took it to heart.

The fourth survey question was in a similar vein, asking the students whether they completed the SH or OQ activities with another student. Seventy percent of students agreed that they did complete the SH activity with another student, whereas only 40% of students agreed that they completed the OQ activity with another student. There may be a few reasons for this. Again, we are not sure whether students would answer this question honestly; however completing the OQ challenge on the computer would be a more likely activity to complete on one’s own, just due to the nature of the activity. The SH challenge involved going to the library and examining a physical model, which would be more of an activity that lends itself to doing with a friend, for both companionship and support. Students might also perceive group work to be more acceptable in terms of academic honesty with this type of a hands-on activity. These students are used to working in pairs or groups in labs that involve a lot of hands-on activity work.

Student responses to the fifth question, indicated that 64% of students agreed that the SH activities helped them to understand the course material and 77% of students agreed that the OQ activities helped them to understand the course material.

Moreover, in answer to the sixth survey question, the majority, 68% and 79% of students agreed that the SH activities and OQ activities were useful, and only 6% and 3% disagreed, respectively.

In terms of whether students found each activity enjoyable, the results were quite similar in that 74% of students found the SH activities enjoyable and 75% of students found the OQ activities enjoyable.

Finally, when asked whether these two activities should be used in the future, 81% of students thought that the SH activities should be used again and 86% of students thought that the OQ activities should be used again.

### Participation Numbers:

<table>
<thead>
<tr>
<th>Participation Bonus Points</th>
<th>Number of Participating Students</th>
<th>Average Number of Points Earned by Each Participating Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Answering Questions During Class</td>
<td>83 (46%)</td>
<td>4.07±4.00(SD)</td>
</tr>
<tr>
<td>2. Completing OnLine Quiz #1</td>
<td>118 (65%)</td>
<td>0.904±0.187(SD)</td>
</tr>
<tr>
<td>3. Completing OnLine Quiz #2</td>
<td>114 (63%)</td>
<td>0.916±0.145(SD)</td>
</tr>
<tr>
<td>4. Completing OnLine Quiz #3</td>
<td>96 (53%)</td>
<td>0.821±0.255(SD)</td>
</tr>
<tr>
<td>5. Completing OnLine Quiz #4</td>
<td>97 (53%)</td>
<td>0.775±0.275(SD)</td>
</tr>
<tr>
<td>6. Completing OnLine Quiz #5</td>
<td>101 (55%)</td>
<td>0.97±0.16(SD)</td>
</tr>
<tr>
<td>7. Completing OnLine Quiz #6</td>
<td>114 (63%)</td>
<td>0.946±0.225(SD)</td>
</tr>
<tr>
<td>8. Completing OnLine Quiz #7</td>
<td>96 (53%)</td>
<td>0.848±0.223(SD)</td>
</tr>
<tr>
<td>9. Completing OnLine Quiz #8</td>
<td>66 (36%)</td>
<td>0.901±0.141(SD)</td>
</tr>
<tr>
<td>10. Completing OnLine Quiz #9</td>
<td>94 (52%)</td>
<td>0.86±0.203(SD)</td>
</tr>
<tr>
<td>11. Heart Model Challenge</td>
<td>47 (26%)</td>
<td>0.9513</td>
</tr>
<tr>
<td>12. Lung Model Challenge</td>
<td>29 (16%)</td>
<td>0.9755</td>
</tr>
<tr>
<td>13. Brain Model Challenge</td>
<td>35 (19%)</td>
<td>0.9854</td>
</tr>
<tr>
<td>14. Lumbar Vertebrae Model Challenge</td>
<td>30 (17%)</td>
<td>0.9683</td>
</tr>
</tbody>
</table>

**Table 1. Student Satisfaction Survey Results.** This table shows class participation data of each of the different bonus activities.
Based on participation numbers (Table 1), it is evident that most students preferred utilizing online quizzes to obtain bonus points rather than finding and completing the pathophysiology model scavenger hunt challenges. This may be due to accessibility and ease of use – it would be easier for students to complete online challenges from home (or elsewhere), then make time to find a model in the library.

Interestingly, at the end of the term, the average number of bonus points (out of 10) collected by each student was 9.53±4.53. With only thirteen out-of-class activities, the numbers of bonus points collected was much higher than anticipated. It had been hypothesized that many factors might actually lead to lower numbers: students might forget, might not have had enough time, might not perceive that these activities had value in their learning, or might be put off by the additional work for relatively small amount of marks. So we were surprised and excited that students did partake in these new activities. In addition, 82 students (n=182) earned more than the ten points required, demonstrating that these students either found that the activities were useful and enjoyable, or perhaps they wanted to ensure that they earned full bonus marks. As a point of note, the instructions were clearly written in several places (in the syllabus as well as their Blackboard Connect gradebook) so we do not think there was any confusion in how bonus points were counted.

**VARK Survey Results**

Interestingly, when asked in the student satisfaction survey (n=119), what type of learner they were: 38.9% of students reported being a visual (V) learner, while 7.5% reported being an auditory (A) learner, 14.5% reported being a read/write (R) learner and 32% reported being a kinesthetic (K) learner.

**Correlations between VARK and Plastic Model Participation.**

<table>
<thead>
<tr>
<th></th>
<th>Heart Model</th>
<th>Lung Model</th>
<th>Brain Model</th>
<th>Lumbar Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>V to model</td>
<td>0.126</td>
<td>0.111</td>
<td>0.100</td>
<td>-0.070</td>
</tr>
<tr>
<td>participation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A to model</td>
<td>-0.035</td>
<td>0.119</td>
<td>-0.177</td>
<td>0.181</td>
</tr>
<tr>
<td>participation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R to model</td>
<td>-0.239</td>
<td>-0.002</td>
<td>0.581</td>
<td>0.115</td>
</tr>
<tr>
<td>participation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K to model</td>
<td>0.127</td>
<td>0.696</td>
<td>0.684</td>
<td>0.026</td>
</tr>
<tr>
<td>participation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conclusion**

Our study found that the majority of students who participated in the scavenger hunt activities found the plastic models and crosswords were useful and enjoyable, and they recommended that they be used in the future. Correlational analysis showed that kinesthetic learners participated the most, perhaps due to their hands-on learning style. Read/write learners were also found to be more likely to participate in the model activities, possibly as the read/write format of vocabulary style crosswords may have added to the appeal and usefulness of this activity for this group of learners.

It was also found that both new student resources (the scavenger model hunt activities and online quizzes) were perceived as being useful, enjoyable, helpful in studying for exams, and valuable in understanding the course material for the majority of students. In the future, we would like to look into ways of increasing the number of models and accessibility of these models for students.

**About the Authors**

Zoë Anne Soon, PhD is a senior instructor. She conducts pedagogical research and teaches many courses at the University of British Columbia Okanagan (UBCO) including: the two-term, first-year Anatomy and Physiology and third-year Pathophysiology for Human Kinetics students.

Melanie Robles, BHK. At the time of this study, Melanie was an undergraduate student and undertook a role in this study as part of her HMKN499 research project.

Stephanie McKeown is the Director of UBCO Planning and Institutional Research. Stephanie assisted in survey design and data analysis.

Heather Hurren, MEd is the Manager, of the Centre for Teaching and Learning, UBCO. As one of her many roles, Heather facilitates educational research projects and in this case was instrumental in delivering student consent forms and ensuring the study was blinded to the instructor.

Table 2. Results of VARK and plastic model correlations (n=119).

Interestingly, it was found that there is a strong correlation between kinesthetic learning and plastic model participation in both the lung and brain model activities (Table 2). The correlation between kinesthetic learning and use of the lung model was 0.696, and was 0.684 for use of the brain model. There was also a strong correlation (0.581) between read/write learning and usage of the brain model. These correlations may indicate that kinesthetic learners are more drawn to hands-on model activities. Each model came with a descriptive card as well as the crossword, which may have attracted read/write learners to participating in the brain model. It is unclear why correlations were found with the brain and lung model and not the heart or lumbar vertebrae model. Timing in the term may have been a factor or perhaps perceived difficulty of each topic.
Literature cited


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Disclosures
No conflicts of interest, financial or otherwise are declared by the author(s). Parts of this study were presented as a poster at the Human Anatomy and Physiology Society conference (May, 2016).
Pulling the Plug on Microscopes in the Anatomy and Physiology Laboratory

Zvi Ostrin, PhD and Vyacheslav Dushenkov, PhD
Hostos Community College (CUNY), Department of Natural Sciences, Room A-507, 475 Grand Concourse, Bronx, New York 10451
zostrin@hostos.cuny.edu, vddushenkov@hostos.cuny.edu

Abstract
Virtual microscopy (VM) has been widely available for more than a decade, especially in clinical settings and medical schools. In recent years the movement away from conventional optical microscopy (OM) and towards VM has been accelerating and several VM websites are now available online and readily accessible to educators. VM can enhance the instructor’s ability to teach the histology component of anatomy and physiology classes, facilitate student learning, save time for both students and instructors, and ultimately save money that can be more productively used for other facets of the laboratory. The many pedagogical and practical advantages provided by VM suggest that now is the time for undergraduate anatomy and physiology programs to consider a transition to VM. doi: 10.21692/haps.2017.024

Key words: Histology, Virtual Microscopy, Educational Technology, Paradigm Shift, Digital Imaging

Introduction
Histology is a central part of the human anatomy and physiology laboratory curriculum. It reveals the microscopic structure of organs and tissues, elucidates the connection between structure and function, provides an understanding of the underlying chemistry through selective staining, and enables the comparison of normal and pathological tissues. For over a century, undergraduate lab work in histology was synonymous with the use of optical microscopes and glass slides. Learning how to focus, view different planes, adjust the light, and pan over tissue sections was a rite of passage for those entering health-related fields.

In conventional histological lab work, researchers and students look through an optical microscope at a tissue suitably mounted on a glass microscope slide. In this fashion, the practice of OM continues a pattern of research and learning that was begun several hundred years ago with Antonie van Leeuwenhoek’s hand-produced microscopes and Robert Hooke’s identification of “cells.” The identification of plant cells by Matthias Jakob Schleiden and animal cells by Theodor Schwann, as well as the pioneering work by microbiologists, were all made possible by the powerful ability of the optical microscope to expand our vision to see structures that were too small to see using the naked eye.

High school and general college biology courses have long emphasized the use of optical microscopes to study suitably prepared specimens mounted on glass slides. Increasingly, however, the OM tradition is being replaced by virtual microscopy (VM). In VM, high-resolution digital files are created by digitally scanning high quality tissue specimens mounted on glass microscope slides. The digitized information is stored on a server in a manner that allows users to access the digital image, and to search (pan) and magnify the image just as with OM. Focusing in multiple image layers and across different focal planes can also be carried out using appropriate technology. Multiple users can access images simultaneously via the Internet if VM data is set up on a web-based platform.

Virtual microscopy images often exceed the viewing quality and resolution of the best optical microscope and glass slide combinations. It must be emphasized that VM is very different from conventional photomicrography, in which static images are created using a camera to take a photograph through a light microscope, e.g. the images found in textbooks, lab manuals, and histology atlases, as well as on PowerPoint slides or in videos. Such static images, which cannot be manipulated by the user, do not meet the definition of virtual microscopy (Wilson et al. 2016). Virtual microscopy has been widely available since approximately 2005 (Ogilvie 2005, Scoville and Buskirk 2007), especially in clinical settings and in medical schools, where funds for the needed technological changes are more readily available than in two-year and four-year undergraduate colleges (Wilson et al. 2016, Vainer et al. 2017). The movement towards VM has been accelerating, and several VM websites are now available online and readily accessible to educators. The generally superior quality and improved access provided by VM suggests that now is the time for undergraduate anatomy and physiology programs to consider a transition from OM to VM.

Moving from optical to virtual microscopy
The histology portion of anatomy and physiology labs has long been a comfortable technological backwater, isolated from the rush of technology. Optical microscopes have improved somewhat in the past fifty years as advances have been made in technology including a shift from monocular to binocular, adding a mechanical stage, incorporating in-base lighting, facilitating two-person viewing, and adding digital and projection capabilities. However, these incremental advances have not had a significant impact on the learning experience of the typical undergraduate student in the histology portion of the anatomy and physiology lab. At many colleges, a student’s exposure to histology in the...
second decade of the twenty-first century is little different than the experience of a comparable histology student at the end of the nineteenth century.

Increasingly, however, individual instructors and entire departments have experimented with modifications to the traditional presentation of histology in the laboratory. At least one college completely replaced OM in its anatomy and physiology classes with high quality photomicroscopy viewed on computer screens. This decision was based on considerations of pedagogy, efficacy, and cost (Hubley and Zeigler 2013, Hubley 2017). The present authors have experimented with using digital devices (e.g. tablet computers), along with a histology software application, either in concert with or instead of OM. We have found that this approach was effective in motivating anatomy and physiology lab students to learn the subject matter (Ostrin and Dushenkov 2016) (Figure 1).

The past decade has seen exponential growth in the number of digital microscopy applications in research and medicine, a phenomenon that is illustrated by the explosive increase in the number of articles published in this field. This trend is mirrored by a similar increase in the number of articles describing the use of digital microscopy in education and the implementation of VM in medical schools (Figure 2). Many departments and institutions have replaced OM with VM in the histology laboratory. The rapid decline of OM is particularly apparent in medical schools, although it is not clear what percentage of institutions in academia or the allied medical fields have shifted from OM to VM. Large universities in the United States, including the University of Michigan (Hortsch 2013), University of Iowa, NYU, and Duke University, have taken the lead in adopting VM technology, citing the obvious pedagogical, efficient, and financial advantages of VM.

Figure 1. Students using digital images, rather than a microscope, to study tissues. Digital technology is effective in motivating anatomy and physiology lab students.

Figure 2. Graph represents the results of a search in Google Scholar (scholar.google.com) on July 13, 2017 to find journal articles from the years 1990-2016 that contain the following search terms anywhere in the article: (a) the exact phrase “digital microscope”; (b) the exact phrase “digital microscope” combined with the word “education.”
Numerous studies, albeit almost exclusively in medical schools, indicate the pedagogical equivalence or superiority of VM to OM in teaching histology and pathology. When the Medical College of Wisconsin converted two of its first-year courses, in cell and tissue biology, and in integrated medical neuroscience, to VM, a survey of students and faculty indicated that VM was very favorably received. Examination scores in courses where students used VM were comparable or superior to courses where students used OM (Krippendorf and Lough 2005). A study of students taking histology at Eastern Virginia Medical School found no significant difference in the test scores of students using VM and students using OM (Scoville and Buskirk 2007).

At the University of Turku, Finland, a comparison of the test performance of medical students taking pathology classes using either OM or VM gave mixed results. Although the VM group had superior test results for normal histology, the OM group had superior results for pathological histology (Helle et al. 2013). At Ghent University, Belgium, there were no significant differences in the test performance of medical students studying histology using either VM or OM (Mione et al. 2013). At the Third Military Medical University in Chongqing, China, test scores of students using VM were significantly higher than the scores of students using OM (Tian et al. 2014). The School of Medicine at the University of Barcelona, Spain, found no difference in knowledge among medical students studying pathology by either VM or OM (Ordi et al. 2015).

A meta-analysis by Wilson et al. (2016) combined the outcomes of twelve studies that compared the effectiveness of OM and VM. The students in the studies were mostly medical students or college undergraduates in either histology or pathology lab classes; 1,978 of the students were in classes that used VM, and 3,950 students were in classes that used OM. The meta-analysis pointed to the pedagogical effectiveness of VM, indicating that the use of VM in the lab had a small but statistically significant positive effect on student learning. Furthermore, students “reported a general preference, or favorable attitude, toward VM over OM.” The authors suggest that improvement in learning may be attributable to both the “ease of access” and “ease of use” of VM over OM (Wilson et al. 2016).

Implementation of VM has become commonplace and generally accepted. In the Fall of 2016, when the University of Copenhagen Faculty of Health and Medical Sciences phased out its use of OM and replaced it with a new automatic VM system, it did not make an effort to compare the pedagogical efficacy of VM and OM, but merely surveyed its users, and reported that the VM system “has been received positively by both teachers and students” (Vainer et al. 2017).

Clinical studies have also shown the efficacy of VM when compared to OM (Ho and Pantanowitz 2017). One clinical study, which used guidelines of the College of American Pathologists to analyze pediatric surgical pathology and cytopathology cases by OM and VM, found that VM was sufficient to adequately review pediatric surgical pathology specimens. The study concluded, however, that the VM review of pediatric cytopathology specimens was less successful and would likely require additional “capture in multiple focal planes” (Arnold et al. 2015). Similarly, when six pathologists used VM and OM to analyze microscopic features seen in dermatitis, they found that VM was sufficient to identify histopathologic features, although it took less time to evaluate cases using OM (Vyas et al. 2016).

Some European countries already accept VM pathology diagnosis. For example, hospitals in the Netherlands and Sweden have replaced OM with VM for diagnostic purposes. The Copenhagen University Hospital (Rigshospitalet) pathology department, which produces more than 800,000 glass slides annually from 95,000 tissue samples, expects to completely replace OM analysis with a VM system by 2020 (Vainer et al. 2017).

On April 12, 2017, for the first time, the U.S. Food and Drug Administration approved a proprietary VM whole slide imaging (WSI) system that will allow pathologists to “to read tissue slides digitally in order to make diagnoses, rather than looking directly at a tissue sample mounted on a glass slide under a conventional light microscope.” The FDA approval came after a clinical study of approximately 2,000 pathology cases, which found that diagnoses made using the approved VM system “were comparable to those made using glass slides.” The FDA noted that the risks associated with VM are similar to those of using conventional OM (Food and Drug Administration 2017).

The digital microscope provides much more information than a conventional microscope, even if the latter has a digital camera. The digital microscope can automatically capture images on several fluorescent channels and on a transmission light channel. It can also stitch together intermediate images and obtain a large area image in high resolution, as well as capture full-focus images of thick objects. The combination of these two options in VM allows complete information to be obtained about the 3D structure of the object.

**Benefits of virtual microscopy in the anatomy and physiology laboratory**

Microscopy typically occupies a significant amount of time in most anatomy and physiology laboratory periods. In our college, three of the fourteen anatomy and physiology I lab periods are devoted exclusively to microscopy. There is one lab in which students learn how to use the microscope, and two labs in which students study the four tissue types and the integumentary system. Most of the other labs in anatomy and physiology I and anatomy and physiology II contain additional lab segments devoted to examining the tissues of specific organ systems. This heavy emphasis on microscopy is probably the same in most college-level anatomy and physiology courses.
However, despite the many hours that students spend in the anatomy and physiology lab using OM to learn histology, the general consensus in our department is that our students get very little productive learning out of the time and effort that they devote to this endeavor. The reasons for this state of affairs are manifold. Large lab class sizes prevent personalized instruction, the many variations among the slides of a single tissue cause confusion, unfamiliarity with the microscope and how to focus it can be frustrating, and the lack of access to microscopes and slides outside of scheduled lab class means that students cannot study the slides on their own.

Student difficulties with OM are not limited to community colleges or pre-nursing anatomy and physiology courses. The same problems appear among students at major universities. For example, at the University of Copenhagen Faculty of Health and Medical Sciences, prior to converting to VM, teachers in the histology and pathology labs often had to provide one-to-one instruction at dual-head microscopes, which “demonstrated that many students were unable to obtain an image on their microscope and also found it difficult to locate relevant areas on their slides” (Vainer et al. 2017).

If we weigh the importance of each lab class hour, and the mass of material that must be taught, understood, reviewed, and mastered, against the de minimis productive learning that most students get from their lab time and effort when using OM, the question that should naturally arise is whether OM and glass slides are necessary in the modern, twenty-first century anatomy and physiology lab. Are the OM skills that we try to instill in our anatomy and physiology students intrinsic to studying histology, or are these skills a distraction and irrelevancy in today’s anatomy and physiology lab? The thesis of this article is that VM, while not a panacea for all the ills of the anatomy and physiology program, can enhance an instructor’s ability to teach histology, facilitate student learning, save time for both students and instructors, and ultimately save money that can be more productively used for other facets of the lab, e.g. physiology equipment.

VM has been shown to be pedagogically sound. Overwhelmingly, studies of OM vs. VM learner performance and preference substantiate the pedagogical efficacy of teaching with VM, which is at least comparable, and in many cases superior, to OM. The earlier cited meta-analysis showed that VM demonstrated “small yet significant positive effect on learner performance . . . indicating that learners experience marked knowledge gains when exposed to VM over OM . . . An analysis of trends in learner perceptions noted that respondents favored VM over OM by a large margin (Wilson et al. 2016). Other studies reported in the literature attest that histology labs using VM were not disadvantaged pedagogically, and histology students generally preferred VM to OM. Additionally; it has been shown that digital technology improves student interest and attention (Ostrin & Dushenkov 2016).

Time and place constraints evaporate when a VM setup is made available to students on the Internet. Access to the histological images is not limited to specific lab hours or specific lab rooms. Students can study the slide images whenever and wherever they want, providing true open access and eliminating any need for “open lab” study time. Several studies reported “strong majorities of students (80.7% - 93.8%) who believed that VM saved them time compared to using the optical microscopes” (Wilson et al. 2016). Additionally, VM may well be beneficial for students with accessibility issues, including vision or physical conditions that make it difficult to use an optical microscope.

Virtual microscopy has the potential to eliminate the steep learning curve inherent in OM. VM reduces, even if it does not eliminate, the frustration that many students have when using OM. Today’s students come to VM already comfortable with the mundane technologies of the twenty-first century, i.e., computers, software, and the Internet. In contrast, the optical microscope, with its glass and metal parts, and its manual adjustment knobs, is arcane and unfamiliar. Many anatomy and physiology students never fully master the complex skills involved in OM such as focusing on a single or multiple planes, adjusting the light, or panning over different areas of the slide. In the typical anatomy and physiology histology lab using OM, weaker students waste valuable lab time looking at unfocused images, the wrong area of the glass slide, or a slide in which the sectioning and staining are inadequate. It is impossible for instructors in large lab sections (we have up to twenty-eight students in our anatomy and physiology labs) to help every student who has OM problems. Consequently, by the end of a typical OM histology lesson a large percentage of students have not mastered what they were supposed to see or learn during the lab period.

Switching the histology lab segment from OM to VM can save lab time that is better used for other purposes. It will enhance the instructor’s ability to present core principles, and can free up lab time for recitation and student-centered activities that enhance learning, such as self-study, group-work, peer-teaching, collaborative education, and team-based learning. VM images can be presented in both labeled and unlabeled versions for student self-study online. The VM images can have explanatory text added, and can be further used in digitized in-class or on-line histology exams and for on-line learning. These options facilitate more uniform and comprehensive lab instruction. Newer instructors, who may be less familiar with the intricacies of histology or the manner in which it is taught in a specific program, will be able to prepare their lessons more effectively.

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Arguments against using virtual microscopy in the anatomy and physiology laboratory

Those who argue against implementing VM present two main reasons for retaining OM in the anatomy and physiology laboratory:

1. Optical microscopy is superior in preparing students for future OM coursework and clinical practice.

2. Optical microscopy is pedagogically superior to VM.

Let us examine these claims.

The first claim suggests that OM experience in anatomy and physiology is needed to prepare students for future OM coursework. Indeed, although students majoring in biology or taking microbiology have a real need for OM skills, particularly if they will be doing fieldwork, they can acquire their OM skills in other biology courses. Many students who take anatomy and physiology have already been exposed to OM in prior course, or are in programs (e.g. radiation technology) that either do not have a microbiology requirement or allow students to take microbiology concurrently with anatomy and physiology. In such cases, the anatomy and physiology lab time spent on OM training is superfluous. Furthermore, instructors at our school report that many superior students who reach microbiology after two semesters of anatomy and physiology still have not mastered the optical microscope. A good argument can therefore be made that the microbiology lab is the best place to teach OM skills, especially those skills particularly relevant to microbiology, including high power focusing and use of the oil immersion lens (a skill that is often not taught in anatomy and physiology).

The first claim also suggests that OM skills will be needed after students graduate and enter the professional world. In our own institution, it is not clear that our students, who primarily train to become nurses, dental hygienists, or X-ray technologists, will have a need for OM skills in their professional careers. The conventional optical microscope is largely not used in medicine and related fields, at least in the United States and Europe. Even in places where it is still being used, OM is being rapidly phased out in favor of VM. Lab tests formerly carried out using OM have long been replaced by automated equipment. For example, in pathology the trend is toward VM or to artificial intelligence (AI). For those professions other than medicine (e.g., veterinary science) that may require proficiency in OM, the microscopes that graduates will encounter on the job will be different than the kinds of microscopes found in undergraduate classrooms, and therefore on-the-job training will be needed.

The second claim suggests that OM is pedagogically superior, because it involves hands-on contact with “real” variable tissues and requires students to focus slides and discover appropriate structures, whereas VM shows only “idealized” pre-focused images of tissues and not the real thing, thereby depriving lab students of contact with actual bits of tissue. According to this line of reasoning, OM provides students with a richer pedagogical experience and a better understanding of cells, tissues, and organs than can be achieved with VM. However, the literature indicates quite the opposite; namely that VM is pedagogically superior to OM as a means of teaching students about tissues. As noted earlier in this paper, student grades on histology tests are higher in classes where students learn with VM. This outcome is not surprising when one considers that VM permits students to learn histology at “any time” and “any place” (Wilson et al. 2016, Hoar 2017), and minimizes most of the frustration and inefficiency of OM. Since OM images and VM images come from the same source, a preserved and stained bit of tissue mounted on a glass microscope slide, there is no greater “reality” inherent in the OM image when compared to the VM image, and there is no evidence that students get a richer experience by using OM.

Students are comfortable with digital imagery, understand its provenance, and readily understand the relationship between glass microscope slides and digital images (Figure 3). Both OM and VM enable the user to change the field of view and the magnification, although of course this operation is more easily done in VM. The variability of normal specimens of the same tissue, as well as comparisons between normal and pathological specimens, can be demonstrated in both OM and VM, though more easily in VM. Focusing is the only operation that can be readily done in OM, but is not generally available in VM as presently constituted. However, since focusing is one of the most problematical aspects of OM for anatomy and physiology students, the fact that VM images are always in sharp focus makes the student’s VM histology experience more productive than OM.

Figure 3. Student using a smartphone to capture a digital image through an optical microscope. Students are comfortable with digital imagery, and understand the relationship between glass microscope slides and digital images.
It is critical that we do not lose sight of the underlying purpose of the histology segments in the anatomy and physiology lab, namely to help students gain an understanding of the micro-anatomy of human tissues and organs, and to connect that understanding to normal and abnormal human physiology. In today’s technological environment, VM is the superior tool for anatomy and physiology instructors charged with teaching histology, and for students who must acquire this knowledge. At the University of Wisconsin-La Cross, OM was replaced by VM in the undergraduate anatomy and physiology labs in 2011. Some instructors were “a bit skeptical” when VM was first implemented, but currently there is a consensus that the conversion to VM has been a success (Hoar 2017). Students taking anatomy and physiology courses at the University of Wisconsin-La Cross can now study histology whenever and wherever they want, and indeed, they tend to do most of their studying for histology outside of the lab, and use their lab time to study specimens and models that are accessible only in the lab room. Test scores on anatomy and physiology exams that emphasize histology increased after the university switched to VM (Hoar 2017).

Converting to virtual microscopy

Once a decision is made to convert the anatomy and physiology labs from OM to VM, there are several issues that need to be addressed, specifically regarding the technical and financial aspects of implementing the new VM technology as well as pedagogical issues that pertain to the use of VM by instructors and students.

Each student in the lab would need access to a computer, either provided by the school or obtained by the student, in order to permit individualized access to the VM images during the lab period. In principle, a regular lab room would not be required for VM work, since computer carts containing a full set of laptops or tablet computers could be moved to any classroom, as long as the room had a projector that the instructor could use to show the class enlarged VM images. Outside of the lab period, of course, students would be able to access the VM images on any of their own digital devices. The institution would need to upgrade Internet and Wi-Fi connectivity to a level that would permit multiple lab sections to have simultaneous high-speed access to the high-resolution VM images. Although the purchase of computers and upgrading Internet and Wi-Fi will incur a cost, the benefit is that there will no longer be a need to service or replace optical microscopes.

VM images, stored in folders called “digital slide boxes,” are freely available to faculty and students over the Internet from a number of academic institutions, including the University of Michigan. Textbook publishers are also getting involved in providing VM resources. Alternatively, a college can create its own customized digital slide boxes from an existing collection of tissue slides. The scanning process, conversion into a digital format, and provision for storage and retrieval can be carried out by the college itself, or by a commercial service that will take responsibility for these steps. Going forward, one can envision a consortium of colleges that would pool their existing glass slide collections into VM format with free access by all of the colleges and their students. In April 2017, a version of such a consortium, the Virtual Microscopy Database (VMD), was launched, and designed as a free resource for researchers and educators, but not students (Lee et al. 2017).

The greatest challenge involved in the transition to VM will likely come from the pedagogical aspect. Instructors will need to become familiar with the new VM images, the web locations of the images, and the VM interface. Instructors will need to modify their teaching and lab presentation in order to take full advantage of the power of VM. The time freed up by not needing to explain the care and the operation of an optical microscope, or to help individual students with lighting, focusing, etc., will now be available for more productive pedagogical purposes. Online and hardcopy instructional materials, as well as lab quizzes on histology will need to be revised in order to reflect the use of VM in the lab.

The above changes do not have to occur simultaneously. A department can start slowly, buying one set of computers, setting up one lab room at a time for VM, using freely available VM images initially before deciding whether to create a customized digital slide box, and modifying the pedagogy in increments. In the end, all of the foregoing changes should be seen as evolutionary, not revolutionary. The changeover from OM to VM can be seen as merely a change in “operating system” or “platform,” since bits of stained tissue on glass microscope slides, which are magnified by some form of optical microscope, form the histological basis for both OM and VM. In OM the glass slide is directly viewed, whereas in VM the image is first stored in a digital format before being viewed.

Conclusion

Although the conventional optical microscope was necessary for viewing histological preparations in the anatomy and physiology lab prior to the current digital age, the manifold advantages of virtual microscopy (VM) in terms of access, use, pedagogy, and cost make it the clear choice today. The movement away from conventional optical microscopy (OM) and towards VM in both the professions and academia has been accelerating. Numerous VM websites are now available online and readily accessible to educators and students. The generally superior quality and the many pedagogical advantages provided by VM suggest that now is the time for undergraduate anatomy and physiology programs and lab instructors who have not yet made the switch to consider and indeed plan transitioning from OM to VM.
About the Authors

Zvi Ostrin PhD, is an Associate Professor in the Department of Natural Sciences at Hostos Community College of the City University of New York (CUNY). He teaches Anatomy and Physiology, and is interested in the pedagogy of the biological sciences.

Vyacheslav Dushenkov PhD, is an Assistant Professor in the Department of Natural Sciences at Hostos Community College (CUNY). He teaches Anatomy and Physiology and has had a longstanding interest in adapting digital technology to the teaching of biology. He is a visiting research professor at the School of Environmental and Biological Sciences at Rutgers University.

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Songwriting to Learn: Can Students Learn A&P by Writing Content-Rich Lyrics?

Gregory J. Crowther1, Allison J. Ma1, and Jennifer L. Breckler2

1Division of Biological Sciences, School of STEM, University of Washington Bothell, Bothell WA 98011
2Department of Biology, San Francisco State University, San Francisco CA 94132
crowther@uw.edu (corresponding author)

Abstract

Writing To Learn (WTL) is a promising pedagogical approach by which students can process scientific content. However, much remains unsettled regarding WTL’s likely mechanisms of action and corresponding best practices, particularly for nontraditional forms of writing, such as the writing of song lyrics about disciplinary content. Here we present pilot data suggesting that, when given music assignments, some anatomy and physiology students are resistant to what we term “Songwriting To Learn” (STL), while others see its potential as a catalyst for learning. We offer recommendations on implementing STL in science courses. Our emphasis is on facilitating and tracking the learning that occurs during the song-writing process, rather than focusing on the final song. Our key recommendations are encapsulated in a template for documenting this along-the-way learning and, in doing so, guiding students through science song-writing assignments that might otherwise seem difficult. We welcome feedback on this template.

Key Words: creative writing, arts integration, STEAM

Introduction

Communication skills, including writing, are recognized as a core competency of biology literacy and practice (Brewer and Smith 2011). Broadly speaking, students’ scientific writing assignments can be categorized as “learning to write” (LTW), where the primary emphasis is on communicating effectively, or as “writing to learn” (WTL), where writing is used more as a tool for learning content (Reynolds et al. 2012). For WTL advocates, writing is not merely a process of reporting what the writer already knows, but deepening one’s understanding of a topic while attempting to write about it (Fry and Villagomez 2012). To the extent that LTW can be distinguished from WTL, we will focus primarily on the latter.

A recent article in this journal (Petzold et al. 2016) explained how creative writing assignments could be used to review course content in anatomy and physiology. Groups of three to four students were presented with various scenarios (e.g. “Your protagonist was enjoying a hike in the mountains after a large dinner that included wine…”) and were asked to write stories that included the roles of several physiological systems. Student reactions to these assignments were mostly favorable. A similar approach, though aimed more at acquiring new knowledge than reviewing previous material, has been reported for a human physiology course (Bunker and Schnieder 2015). Various health sciences instructors have experimented with alternative types of writing such as poetry assignments, though these often target interpersonal and ethical aspects of medicine rather than scientific ones (Brown 2015, Jack 2015, Cowen et al. 2016).

Our own interest in student writing extends to songwriting, which also rewards student creativity but comes with unique pedagogical challenges imposed by the additional constraints of the musical form (Crowther 2012). In most studies of the use of educational STEM music, students are engaged as consumers, rather than producers, of content-rich songs (Governor et al. 2013, Lesser et al. 2016). Nevertheless, we seek to make songwriting in anatomy and physiology more feasible for students themselves to undertake, and to evaluate its impact on their learning. As a first step toward these goals, we present some preliminary data from student surveys and offer a template for possible use in student songwriting assignments.

Students Prefer Instructor-Written Lyrics Over Writing Their Own

One of us (GJC) regularly uses music in teaching anatomy and physiology courses (Crowther et al. 2015), including Biology 241-242 (human anatomy and physiology for pre-nursing students) and Biology 351-352 (comparative anatomy and physiology for biology majors) at a Primarily Undergraduate Institution in the state of Washington. We assess this integration of music into the curriculum in part by distributing IRB-approved surveys to students after obtaining the students’ informed consent.

We surveyed students in recent anatomy and physiology courses (Biology 351, Fall 2015; Biology 241, Spring 2016; and Biology 242, Summer 2017) about four possible musical interventions:

(A) students listen to instructor-written songs
(B) students complete a song by adding a line to an incomplete instructor-written song
(C) students write brand-new songs in groups
(D) students write brand-new songs as individuals.

continued on next page
Each class experienced intervention A. The Biology 351 students also tried B, and the Biology 241 students also tried C and D. Students were asked to rate each intervention’s perceived or projected impact on their learning as “very helpful,” “helpful,” “neither helpful nor unhelpful,” “unhelpful,” or “very unhelpful.” The vast majority of students in both comparative and human anatomy and physiology courses rated the instructor-written songs as “very helpful” or “helpful,” whereas ratings of the options to finish a song or write a new song were not as consistently positive (Figure 1).

Our surveys did not fully explore the reasons why students tended to prefer instructor-written songs over their own, but we speculate that most students lack training in songwriting and find the process challenging. This idea is consistent with our data for the one course (Biology 241, Spring 2016) when we required every student to write or co-write two short songs (i.e. interventions C-D above). Of the 25 students from whom informed consent was obtained, several expressed frustrations with the writing process and/or the results. Examples of direct quotations included the following:

1.) It doesn’t feel natural to me. I will stick to the traditional, comfortable way of studying.
2.) [I] like music but not writing it myself.
3.) It was hard to come up with a jingle that covered more than the basics.
4.) I never felt like I could get enough information into the song.
5.) I liked the idea, but the result, I was not happy with.
6.) It stressed me out feeling like I had to share my song in front of the class.

Nevertheless, 12 of the 25 participating students made comments to the effect that writing their own songs helped them explore the material more deeply and/or understand it better. Direct quotations included the following:

1.) It made me look deeper into the concepts and incorporate more into my jingles.
2.) Writing our own jingles made me think harder about the material.
3.) I think that writing jingles requires deep conceptual thinking about subjects.
4.) Writing my own jingles helped me to simplify and understand the contents.
5.) I felt that writing my own song was good in that it made me really understand the content.

Thus, our survey results collectively suggest that songwriting assignments are difficult for many students, yet may have the potential to catalyze deep learning. In addition, we know from our own songwriting efforts (see http://faculty.washington.edu/crowther/Misc/Songs/) that one can learn a lot of anatomy and physiology from trying to concisely and correctly convey content through song lyrics. This led us to the idea of creating a song template for students, which would help students write songs, but also increase their metacognitive learning (Tanner 2012) during the songwriting process itself. The suggestions below may help students learn anatomy and physiology through songwriting, by mimicking the process that we (GJC) have developed and used ourselves.

**Instructor Strategies for Facilitating and Monitoring Student Songwriting**

WTL, whether music-related or not, gives students the intellectual “wiggle room” to focus on aspects of particular interest to them. For WTL assignments, no two students will learn exactly the same thing because each will explore different nooks and crannies within the assigned content.
area. Moreover, and perhaps most interestingly, the many questions, bits of research, and decisions that arise will not necessarily be reflected in the final written piece, which also limits the value of traditional summative assessment. This may be especially true for song lyrics, in which compactness may preclude the longer explanations in more typical writing submissions. In this respect, the process of songwriting resembles the process of concept mapping, in which short phrases are generated and then used in idiosyncratic ways by each learner (Kinchin 2014). In others words, the greatest value of such exercises may be the learning that occurs all along the way, rather than the final products that they generate.

As we join the community of educators studying WTL, we are taking a special interest in this along-the-way learning (which may be downplayed by WTL rubrics that focus on finished products). To this end, we recommend that students write notes in individual journals that document their actual writing process, including the individual questions, research, and decision-making points that they encounter along the way. We further recommend that students distill such journaling into a template (i.e., flow chart) highlighting key steps of the process (see example in Figure 2).

The songwriting template shown in Figure 2 is structured to perform two functions: to give students a clear, easy-to-follow road map for writing a song, and to help them document the learning they do while writing it. Regarding the first function, Figure 2 shows two areas of work (i.e., science content and music) that initially can proceed somewhat independently (a student can initially focus on either the science side or the music side) but that eventually converge with their decisions on how to express the science musically. Together, the first and second functions could bolster student metacognition as the science content is developed and revealed during the writing process.

As indicated in Figure 2, we suggest that students write a song parody (i.e., borrow a tune already known to them) for their early songwriting attempts, rather than writing a completely original composition with a novel melody. This suggestion is based on our empirical observation that parodies are usually preferred by students. In the pilot study mentioned above, Biology 241 students were allowed to submit either parodies, raps, or songs with original melodies. Of the 46 songs submitted, 35 were parodies, 6 were raps, 4 were of an unstructured format, and 1 was an original composition. Selecting a parody helped students to write the lyrics quickly; the self-reported assignment completion time was 21 ± 7 minutes (mean ± S.D.). This limited time-on-task was also likely influenced by the low point value of the songwriting assignment (i.e., less than 1% of the total class points).

As an initial test of the Figure 2 template, one of us (GJC) kept a journal while writing an anatomy and physiology song on the blood clotting cascade, which he then used to fill in the template. The completed template (Figure 3) documents several refinements of his own previously underdeveloped knowledge of this content area. For example, in researching factor VIII’s exact role in the cascade, he learned that it was a cofactor rather than an enzyme per se, which helped him realize that other proteins in the pathway (e.g., factors III and V) are cofactors as well. Thus, Figure 3 demonstrates the principle that real science may be learned during a songwriting exercise!

In the near future, we plan to study student songwriting by asking students to write songs, including the use of journaling and templates to document their songwriting process. We can then collect their written templates to analyze their learning and to see whether guided songwriting can be made feasible for most or all students.

To assess the impact of (song)writing on learning, we will examine the content areas selected by the students, the level of detail presented, and the frequency of tasks representing higher-order cognition in Bloom’s taxonomy (Crowe et al. 2008). Decision-making points are of particular interest to us, and we will gauge how students approach and apply

Figure 2: A template to help students write science song parodies and document their learning and decisions along the way. In this example, we recommend writing parodies of existing songs (MP1) because we find that students prefer to write this type of song.
their reasoning to decisions on the template. We will also provide a few visual icons which students can optionally add to decorate their templates so we can tabulate students’ sentiments about the various steps in the songwriting process (i.e., difficult, fun, fosters learning; see Figure 3) which will inform our future study design. We plan to ask students to select content that is challenging to them, to see whether the songwriting process fosters deeper understanding of difficult material. Finally, we will seek evidence that the hoped-for enhancement of students’ metacognition is actually occurring.

We welcome readers’ suggestions as we continue our planning.

About the Authors
Dr. Greg Crowther will move to Everett Community College in January 2018 after 14 years of postdoctoral teaching and research at the Seattle and Bothell campuses of the University of Washington.

Allison Ma, a Seattle native, received a B.S. degree in Biological Sciences from UW-Bothell in 2016. She hopes to become a Doctor of Podiatric Medicine.

Dr. Jennifer Breckler was a “bench” scientist for over 20 years, focusing on muscle contractile proteins and intermediate filament proteins. She has performed science education research on learning styles, career choices, and the use of writing and music to enhance student learning of physiology.

Figure 3: An example of how the template in Figure 2 was used to document the process of writing the lyrics of a song “I’m Clotting Factor VIII, I Am,” as a parody of the song “I’m Henry VIII, I Am.” Parody lyrics (http://faculty.washington.edu/crowther/Misc/Songs/viii.shtml) were written by the first author (GJC). Three weather icons were selected by the author to indicate parts of the writing process that were fun (sun) or hard (cloud) or that constituted new science learning (lightning).
Literature cited


Abstract

The ePortfolio is a tool for students to display academic accomplishments. It uses a learning-orientated approach that allows students to more fully engage in the academic process within and across disciplines. Use of the ePortfolio in anatomy and physiology encourages students to incorporate the hierarchy of structure, from chemistry to cells to tissues, and reinforces the significance of the integration of body systems. Reflection on the learning process becomes an integral part of the final ePortfolio creation. In anatomy and physiology labs, ePortfolios give students the opportunity to easily compile and manipulate data from lab exercises and add images from multiple sources to form a comprehensive electronic laboratory notebook (ELN). Anatomy and physiology students have expressed appreciation for the opportunity to have a centralized location for archiving course content and for the benefits that come from being asked to take time to reflect on their learning. doi: 10.21692/haps.2017.026

Key Words: artifacts, ePortfolio, integration, pedagogy, reflection

Introduction

An ePortfolio is a digitized collection of artifacts that serves as a means to display learning accomplishments. It is in itself a learning pedagogy. The ePortfolio allows students to share artifacts for the purposes of demonstration of skills and accomplishments, reflections, commentary, and peer/instructor evaluation. As a learning-oriented approach that demonstrates student achievements towards learning outcomes, ePortfolios allow for active participation in the learning process. They exhibit student competency in knowledge, skills and techniques, and through student self-reflection, give insight into the challenges and struggles the student experiences. An ePortfolio can become a powerful medium for expressing and assessing integrative learning when instructors are purposeful in defining the components and designing the grading rubric.

Pedagogical Support for ePortfolios

There is a perception in education that authentic learning occurs best when the learner is an active participant in the process. ePortfolios can be used to shift the locus of control from the teacher to the student, thereby nurturing student engagement. When students incorporate artifacts from multiple disciplines and are asked to synthesize and reflect on them, ePortfolios become a vehicle for developing integrative knowledge and skill (Bryant and Chittum, 2013). The use of ePortfolios offers a means of surfacing new evidence of learning beyond the traditional educational assignments and exams. It allows students to showcase and make connections between the learners’ unique and varied learning experiences and demonstrates competency for designated course learning outcomes. By developing these showcases, students are also creating tools that can demonstrate competencies and abilities for employment or application to graduate programs (Penny-Light 2016). Deneen and Schroff (2014) found emerging evidence that ePortfolios contribute to the development of high-value outcomes including metacognition, which is a competency closely related to early career success.

Dannenberg et al. (2016) from the University of Alaska Anchorage (UAA) explored opportunities for integrating evidence-based learning through the use of ePortfolios. After six years of incremental development, the use of ePortfolios is now campus-wide. From the beginning a faculty-led taskforce had a driving thought that ePortfolios were more than a mere tool for displaying work. The integration of ePortfolios supported pedagogy that was already happening inside the classroom. In a similar example, Dr. Yang, Associate Professor at Prince of Wales Clinical School, UNSW Australia, incorporated the use of ePortfolios to assist students in their learning in Cancer Sciences, an upper level undergraduate course. The ePortfolio was composed of distinctively interactive aspects including formal and informal assessment, discussions, goals, reflections on learning both on and off campus, and analysis of the student’s strengths and weaknesses. The ePortfolio specifically targeted students’ life-long and life-wide learning (Yang, 2016). Life-wide learning refers to students learning important lessons throughout their entire college experience, not just in the classroom (Ecan, 2016). Students then wrote forthrightly in their ePortfolios and received periodic and final feedback and evaluation. They were encouraged to practice and improve their reasoning skills (Yang, 2016). Students were invited to think and act like scientists and to become professional or scientific inquirers in the field through learning scientific concepts and techniques. Student ePortfolios and final

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summaries were assessed using an integrative learning value rubric developed by the AACC in the course (Yang, 2016).

The Role of the ePortfolio in the Classroom

The creation of the ePortfolio requires students to review their course content and identify selections that exemplify competency of knowledge and application in those topics. Drafting text, creating videos, and explaining illustrations engage the student in the content differently from preparing for unit exams and further reinforce the content. One of the challenges in teaching anatomy and physiology is incorporating the hierarchy of structure throughout the course and reinforcing the significance of how the body systems are integrated. The details of chemistry, cells, and tissues that are covered either in pre-requisite courses or in the early weeks of an initial anatomy and physiology course can be incorporated into other anatomy and physiology courses when pertinent information is contained within an ePortfolio. The ePortfolio is a tool for students to explain how body systems are integrated using various homeostatic mechanisms. Through the use of ePortfolios students are able to connect previous content to new concepts, thus the linking of information more efficiently.

Learning involves a process. Some approaches lead to achievement and other attempts are less successful. Metacognition can be intentionally achieved when students reflect on their learning journey. The ePortfolio is a means by which students can easily highlight significant experiences and later reflect upon them. Reflection involves higher order thinking beyond the facts and the organizational framework. Reflection engages the student in active learning and directs them to develop an internal locus of control.

The Role of the ePortfolio in the Lab

Eynon, Gambino, and Török (2014) provide several examples of improved undergraduate student success measures as a result of implementation of ePortfolios. The majority of their data reflects traditional, didactic examples and the use of ePortfolios in laboratory environments can have a similar impact. In the majority of anatomy and physiology laboratory experiences students use either standard or customized lab manuals created through major publishers such as Pearson, McGraw Hill, and Morton. Although valuable for student success, these manuals do not offer the opportunity to easily compile and manipulate data from lab exercises, nor do they offer the ability to add images from microscope slides, online images, or photos taken from specimens or the models used in lab. Use of electronic laboratory notebooks (ELNs) is increasing in undergraduate education (Johnston et al. 2013), but for many students whose lab experiences are limited to anatomy and physiology, microbiology, and maybe general biology and/or general chemistry, the cost of an ELN in addition to the current lab manual may be prohibitive.

Paper lab manuals provide space for data collection but often do not provide a means for the compilation, analysis, and comparison of results from all participants in the lab section, or across multiple lab sections. Through the use of electronic data collection in software such as Microsoft Excel, students can collect, share, and then archive their results in their ePortfolio. Subsequently, students can provide analysis and reflection on their lab experiences, which they can refer to in preparation for lab practical exams. For students who pursue nursing and allied health clinical degrees the ability to refer back to these lab results may be integral in their interpretation of related clinical applications.

In microscopic and dissection labs, students may have representative images in their manuals that differ from their actual slides or specimens. Through the use of an ePortfolio students have the opportunity to take their own photos of their dissection and then directly annotate important features and cues to assist in identifying structures on future lab assessments. In some microscopic labs, images can be captured from microscopes and shared with students. In other cases, students seek online sources for microscopic images, which could then be incorporated into their ePortfolio archive. Through access to multiple images rather than the limited options in the lab manuals students can reduce the likelihood of misinterpretation of anatomical and microscopic features.

Many students take photos of lab models or seek other examples through online sources. The ePortfolio provides students with a centralized location to archive these images and provide their own narrative on the relationships and functions of the structures. Subsequently, students create their own library of content to which they will have permanent access, which will be a valuable tool in future coursework, especially for those students in nursing or allied health programs.

Although the value of the archive and narrative/reflection on learning benefits of the ePortfolio in the anatomy and physiology lab cannot be overstated, the ePortfolio is also an excellent venue for student lab presentations. All too often laboratory instructors rely solely on the lab quizzes and exams as the means of assessing the learning outcomes. Requiring students to create an ePortfolio that represents their achievements and challenges in anatomy and physiology lab can provide substantive evidence of student learning. By including a requirement for self-reflection, students will gain an appreciation for the learning they have achieved.

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Anatomy and Physiology Student Perspectives on ePortfolios

During the 2016-2017 academic year ePortfolios were implemented in select anatomy and physiology courses at Baptist College of Health Sciences. Students were instructed to create an e-Portfolio “showcase” using either the Via LiveText software (piloted by the College) or the Wix.com free online software. The instructions required that the showcase include at least 3 “artifacts” or “representations of learning” which could include excerpts from assignments, case studies, quizzes, exam questions, or summary notes on a particular topic. Students were strongly encouraged to not limit their artifacts to their “best” work, but rather to choose topics they initially struggled to learn. As the course progressed and their study skills improved additional artifacts should demonstrate significant improvement and/or achievement. In addition, for each artifact or “representation of learning” the student had to provide a “reflection” document that discussed their strengths and/or weaknesses regarding the learning, the value of the artifact as it applies to future courses, and the value of the artifact as it applied to their future profession.

In the three anatomy and physiology courses included in the initial implementation, 51 students completed ePortfolios. Additionally, nine students enrolled in Pathophysiology built upon their initial anatomy and physiology showcase to demonstrate application of anatomy and physiology concepts in understanding the pathophysiology of several disease states. Student feedback was universally positive, with many expressing appreciation both for the opportunity to have a centralized location for archiving course content and for the benefits that came from being asked to take time to “think about my own strengths and weaknesses in learning”. Faculty reported that they too were able to improve their approach to teaching certain topics after reading the reflections and gaining insight into the challenges students face.

Lessons Learned

As with any new pedagogical approach or software tool there are challenges in implementation, unanticipated events, and process issues. Some of the lessons learned from an ePortfolio implementation may be unique to the institution or the choice of software, but others are universal and worthy of mention. First amongst the latter category is the challenge many students face in constructing meaningful reflections. Faculty from Baptist College of Health Sciences found that many of their younger students had never been asked to evaluate their own metacognition or reflect in any way on the learning process. As a result, initial ePortfolio submissions consisted of simple statements that lacked significance and depth of thought. In addition to the weak reflections, few students had ever viewed ePortfolios, which limited their reference point for construction of quality learning examples.

To address both these concerns, faculty developed their own sample portfolios and sought online examples to provide guidance to their students. Allowing students some class/lab time to share and collaborate while developing their ePortfolios fostered peer-peer learning, generating excitement over the accomplishments of others and appreciation of the value gained from the reflection and the archiving of information. Additionally, creating incremental due dates as students developed their ePortfolios minimizes potential student frustrations. With a single, end-of-course due date students may receive a poor grade because they left the work to the last minute, did not fully understand the requirements, or did not find value in the ePortfolio assignment.

Although the majority of the students who participated in the Baptist College of Health Sciences first year implementation found the ePortfolio to be a very valuable tool, there were a few students who struggled to appreciate its benefits. These students failed to see the value of reflection on learning in a science course. Predominantly these students struggled to master the anatomy and physiology content and subsequently did not have the time to devote to the ePortfolio assignment. Unfortunately, these opinions are likely to be shared by other anatomy and physiology students. ePortfolios are not only a tool, they are a pedagogical process. Faculty must use the ePortfolio as a learning approach that demonstrates to students the effectiveness of archiving course content and self-reflection as a means to develop strong metacognition. It is the responsibility of the faculty to effectively communicate to their students the importance of “thinking about learning”. This reflective process will improve content retention and the ability to apply this knowledge in the current and subsequent courses as well as in their future careers.

About the Authors

Lisa J. Hight, EdD is a Professor of Biology at Baptist College of Health Sciences in Memphis, TN where she has worked since 1995. She has a BS in Biology from Union University, a MS in Biology from Austin Peay State University and EdD in Instruction and Curriculum Leadership from University of Memphis. Her research interests are focused on histology and development of instructional methodology.

Michelle A. McDonald, MS is the Chair of General Education and an Assistant Professor of Biology at Baptist College of Health Sciences in Memphis, TN where she has worked since 2003. She has a BA from the University of North Florida, a Masters of Chemical and Life Sciences from the University of Maryland, College Park and she is currently pursuing a Doctorate of Public Health with a Specialization in Epidemiology from Capella University. Her research interests are focused on both chronic and infectious diseases.
Literature cited


Observation of Student Behaviors of Watching Online Tutorial Videos and Strategies to Increase Engagement

He Liu and Mary Vagula
Department of Biology, Morosky College of Health Professions and Sciences, Gannon University, Erie, PA
liu017@gannon.edu (corresponding author)

Abstract
This article examines the manner in which students watch videos and the strategies instructors can use to increase student engagement with the content of the videos. In this study, a tutorial video of a lab procedure was recorded and used in the teaching of a physiology laboratory course. Student video-watching behaviors were observed when a 10.2-minute video was given alone and when it was split into three shorter segments that were associated with quiz questions. Both the number of times the video was played and the number of times the video was allowed to run to completion were doubled when the video was split into three short sections. Students gave more positive feedback when videos were shorter and quiz questions were included. Our observations in this case suggest that shorter videos with quiz questions are effective methods to increase student engagement when an online video tutorial was used in teaching. doi: 10.21692/haps.2017.027

Key Words: video-watching, online video, student engagement

He Liu and Mary Vagula presented a poster on this laboratory module at the 31st HAPS Annual Conference in Salt Lake City, Utah in May 2017.

Introduction
Since the current generation of students grew up with YouTube (founded in 2005), more and more multimedia tools have been used in higher education with the hope of increasing student engagement with course content. However, the average length of time spent on watching an online video is 2 minutes 42 seconds (2.7 minutes). Only four percent of the audience spends more than 10 minutes on a video (ComScore 2017). Nearly two-thirds of consumers prefer the length of videos they watch to be shorter than 60 seconds (VideoStats 2017). This article examines the manner in which students watch videos and the strategies instructors can use to increase student engagement with the content of the videos.

In this study, a tutorial video of a lab procedure using ELISA was recorded and used in the teaching of a physiology laboratory course. Through the statistics of the hosting website, vimeo.com, we observed student viewing behaviors, with the video alone and with the video split into three shorter segments. When the video was presented in three short segments, it was associated with quiz questions. On average, students spent 5.2 minutes on the 10.2-minute demonstration video when the video was given alone and 11.7 minutes when the video was split into three segments and followed by quiz questions. Both the percentage of times the video was played and the number of times it was allowed to run to completion were doubled when the video was split into three short segments. Student feedback was more positive for the shorter segments of video that were followed by quiz questions. Our observations in this case suggest that the use of shorter videos and follow-up quizzes are effective strategies for increasing student engagement with tutorial videos.

Materials and Methods
Video capture and editing: Video clips were recorded using a digital camcorder and a tripod. The recorded clips were edited using Windows Moviemaker under Windows 7 and 10. Titles, photos, and captions were added to the video. Some repetitive steps were fast-forwarded at 8x speed to save time. At the end, the 40-minute experimental procedure was condensed into a 10.2-minute (10:12) video. The video was saved into an AVI file (1920x1080 dpi, 151MB). Later, the video was split into three segments with lengths 3.0, 4.8, and 2.5 minutes based on the major steps of the experiment. The hosting website for this study was vimeo.com.

Student behavior observation: The demonstration videos were uploaded on video.com. Students were sent links to the videos one week prior to their lab. Video Plus membership was purchased to view the user statistics (number of play, number of finish, total time watched, average time per view). Student feedback was collected through an anonymous survey. The Institutional Review Board of Gannon University approved this study, IRB #15-10-01.

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Results
The video demonstration was recorded, edited, uploaded and released in the fall 2016 semester. All 37 students were sent a link to the video in the week prior to the designated lab. The video was only played 27 times during the week prior to lab (0.7 play/student, Figure 1C). We noticed that students tended not to watch the video to completion (Figure 1A). The average time spent per student on this 10.2-minute video was only 5.2 minutes (Figure 1A). For each time the video was played, the average percent of the video that was viewed was 51% (Figure 1B). The video was watched to completion only 12 times. On average less than one-third of the students finished the video even when assuming that no one played it repeatedly.

In order to increase student engagement and make this video more effective in preparing students for the lab, two modifications were implemented in the spring 2017 semester with 33 students in the class.
1. The 10.2-minute video was divided into three segments of 3.0, 4.8, and 2.5 minute time intervals.
2. Three questions were developed for an online quiz requiring students to self-examine their video viewing behavior (Figure 2). Students were required to answer these questions before coming to the lab. The scores were counted towards their final grade (~0.5%).

Students spent more total time (11.7 vs. 5.2 minutes per student) watching the shorter videos segments (Figure 1A) associated with the online quiz. The average watching time during shorter videos (11.7 minutes) was longer than the combined length of the three short videos (10.2 minutes) (112% in Figure 1B). This is due to repeated playing of the video by some students. There were 44.7 plays on average for each video and only 33 students who had received the links (Table 1). The video was played twice as often per student (1.4 vs 0.7) and viewed to completion twice as often (0.7 vs. 0.3), but the finish/play ratio remained about the same. This is due to the fact that more students repeated the video. It is likely that students were able to find the required answers by the second time of viewing and they stopped at that point. All the observed and calculated data are listed in Table 1.

Student feedback was collected by an anonymous survey. Overall, student feedback was consistent with the behaviors that had been observed. A higher majority of students (97% vs. 75%) felt that the length of the video was good. Fewer students (3% vs. 25%) complained that the video was too long.

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Figure 1. Video-watching statistics with one video (10.2 minutes, blue columns at left) vs. three segments (3.0, 4.8, and 2.5 respectively) and quiz questions (green columns at right). A. Students spent more time on watching multiple videos (the sum of watching time on the three segments). B. The average percentage of watching time is much higher when the video was given in three segments and with quiz questions. C. More students tended to start the video(s) and more to finish the video(s). The finish/start ratio remains about the same (0.4 vs. 0.52).

Figure 2. Student feedback suggested shorter, multiple videos with quiz questions (green columns at right) were more welcomed by students, compared to one longer video (blue columns at left). A. A higher majority (97% vs. 75%) of the students felt the videos had good lengths and less (3% vs. 25%) complained the video was too long. B. Students felt the videos were helpful in either way but slightly favor multiple videos with quiz questions. C. Most students watched the videos on the same day or the day before the lab. A Higher percentage of students watched earlier when the video was given in multiple segments with quiz questions.

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(Figure 2A). Most students felt the videos were helpful and more students chose the most favorable answer "Definitely a lot" (Figure 2B) than a less favorable answer. Consistently, the highest percentage of students watched the videos on the day of the lab or the day before the lab (Figure 2C). This behavior is understandable given that college students have busy schedules. A higher percentage of students watched 1-2 days earlier when the video was given in multiple segments with quiz questions, probably because they were motivated or driven by the need to complete the quiz questions for the grades.

### Conclusion

Based on our observations and student feedback, it is more effective to implement a tutorial or demonstration video online when:

1. The video is given in shorter segments (2 to 5 minutes).
2. Quiz questions are included to guide student viewing of the videos.

We feel confident that students can be encouraged to spend longer than the 2.7-minute average viewing time of an online video. A video shorter than five minutes is still in the comfort zone of most students in this study, especially with the motivation of answering quiz questions for extra credit.

### Table 1. Observed and Calculated Data of Student Video-Watching Behavior

<table>
<thead>
<tr>
<th>Video</th>
<th>Long Video</th>
<th>Average of 3 Videos</th>
<th>Video 1</th>
<th>Video 2</th>
<th>Video 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Video</td>
<td>10.2</td>
<td>3.4</td>
<td>3.0</td>
<td>4.8</td>
<td>2.5</td>
</tr>
<tr>
<td>Number of Students</td>
<td>37</td>
<td>33</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Plays</td>
<td>27</td>
<td>44.7</td>
<td>52</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>Finishes</td>
<td>12</td>
<td>23.3</td>
<td>25</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Total Minutes Watched</td>
<td>193</td>
<td>n/a</td>
<td>136.1</td>
<td>175</td>
<td>74.27</td>
</tr>
<tr>
<td>Average Minutes per View</td>
<td>7.15</td>
<td>n/a</td>
<td>1.85</td>
<td>4.27</td>
<td>1.82</td>
</tr>
<tr>
<td>Average Percentage Watched in Each Video</td>
<td>72%</td>
<td>81%</td>
<td>73%</td>
<td>93%</td>
<td>76%</td>
</tr>
<tr>
<td>Minutes/Student</td>
<td>5.22</td>
<td>n/a</td>
<td>4.12</td>
<td>5.30</td>
<td>2.25</td>
</tr>
<tr>
<td>Percentage of Content Watched/Student</td>
<td>51%</td>
<td>112%</td>
<td>136%</td>
<td>110%</td>
<td>90.60%</td>
</tr>
<tr>
<td>Plays/Student</td>
<td>0.73</td>
<td>1.35</td>
<td>1.58</td>
<td>1.24</td>
<td>1.24</td>
</tr>
<tr>
<td>Finish/Student</td>
<td>0.32</td>
<td>0.71</td>
<td>0.76</td>
<td>0.76</td>
<td>0.61</td>
</tr>
</tbody>
</table>

* n/a: at these places, average values don’t apply.

### About the Authors

He Liu is an Assistant Professor and the Interim Chairperson of the Biology Department of Gannon University, Erie, PA.

Mary Vagula is a Professor of Biology at Gannon University, Erie, PA.

Dr. Liu and Dr. Vagula teach various courses at Gannon University including multiple sections of Animal Physiology and Animal Physiology Lab. They are both members of several national societies including Human Anatomy and Physiology Society (HAPS).

### Acknowledgement

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Student Perceptions of the Importance of Evolutionary Knowledge in Medicine: A Case Study from an Undergraduate Anatomy & Physiology Course.

Mark V. Tran, PhD  
University of Cincinnati Blue Ash College, 9555 Plainfield Rd, Blue Ash, OH 45236  
Tranmk@uc.edu

Abstract  
Biological evolution is not emphasized in medical education and undergraduate anatomy and physiology courses. This omission in medical education has contributed to the development of a number of avoidable medical problems such as antibiotic resistance in bacteria. This article presents the results of a survey administered to undergraduate anatomy and physiology students that aimed to understand student opinions on the importance of teaching evolution to medical professionals. Results of the survey suggest that students believe biological evolution has played a major role in shaping human anatomy and physiology and that medical professionals should understand biological evolution. The goal of this manuscript is to raise awareness for the importance of teaching evolutionary concepts in undergraduate anatomy and physiology so that future medical professionals can use this knowledge to better serve their patients. doi: 10.21692/haps.2017.028

Key Words: evolution, health, opinions

Introduction  
Biological evolution is a central theme in the study of modern biology. This sentiment is reflected by the widespread belief among biologists that “nothing in biology makes sense except in the light of evolution”; a statement that was made by Dobzhansky in 1973. The forces involved in evolutionary change, such as natural selection (Darwin 1859), can be observed across all levels of biological organization from cells to ecosystems. Accordingly, most biologists would agree that these evolutionary processes have played a pivotal role in shaping the structure and function of the human body (Bull 1994, Nesse 2007).

Despite the widespread understanding that evolution has helped shape the anatomy and physiology of the human body, the training of medical professionals generally puts little, if any, emphasis on understanding the role of biological evolution in human medicine (Nesse et al. 2010). Instead, medical research and practice tend to emphasize proximate questions (e.g. “How does this drug work?”) while simultaneously deemphasizing ultimate questions (e.g. “Why does this drug work?”) (Nesse 2007). However, many evolutionary biologists, and other proponents of the emerging discipline of “Darwinian” or “Evolutionary” medicine (Bull 1994, Nesse 2007), believe that a thorough understanding of evolutionary concepts and ultimate questions is the key to understanding the natural history, pathology, and treatment of numerous human diseases (Bull 1994, Nesse 2007).

Indeed, numerous topics pertaining to human medicine, such as the susceptibility to disease and prevalence of human diseases, would make more sense when viewed in the light of biological evolution. For example, the virulence patterns of human pathogens can be better understood by studying the evolutionary relationships (e.g. evolutionary arms race) between pathogens and their hosts (Bull 1994, Levin 1996, Dethlefsen et al. 2007). Numerous scholars have argued that virulence patterns are shaped and maintained by selection pressures acting on both the pathogen and the host (Levin 1996, Dethlefsen et al. 2007). For example, viruses that have fast transmission times, such as Ebola, tend to have high virulence due to decreased selection pressure favoring the survival of its host (Dethlefsen et al. 2007). Additionally, high virulence is often seen in pathogens that have long histories of infecting animals, but only recently began being transmitted to humans (Bull 1994). Understanding the dynamics of this evolutionary relationship is fundamental to developing effective long-term treatments for these diseases.

Another major problem faced by modern medicine is the evolution of antibiotic resistance among bacterial pathogens. However, this problem could have been mitigated, or avoided altogether, if medical professionals had a deeper functional understanding of the evolutionary forces, such as natural selection, that shape antibiotic resistance. Thus, the lack of emphasis on training medical professionals in evolutionary concepts has created a major global human health concern.

The simplest method of unifying the fields of evolutionary biology and medicine, and thus increasing the efficacy of medical efforts to combat disease, is to increase the awareness and understanding of evolutionary topics.
pertaining to medicine among medical professionals. Owing to this lack of emphasis on evolutionary knowledge in medicine, there is a fundamental divide in the education of students pursuing strictly biology majors and those pursuing degrees in pre-health professions.

While evolutionary concepts are a staple of most undergraduate biology classes, courses geared towards pre-health professionals, such as Anatomy and Physiology, do little to expose students to the importance of biological evolution in human medicine. This is partly due to the lack of emphasis in the medical field on encouraging the study of evolution and the lack of perceived importance of evolutionary knowledge among medical professionals. This lack of emphasis pervades the instructional concepts and techniques used in pre-health professions courses, such as anatomy and physiology, in which little, if any, evolutionary knowledge is transferred to students.

This begs the question of whether pre-health profession students should be taught evolutionary concepts as they relate to course concepts, such as the structures and functions of the human body in anatomy and physiology courses. This study aimed to analyze the opinions and knowledge of undergraduate students pertaining to biological evolution and its importance in medicine. The study was geared towards anatomy and physiology since this class is a requisite for many pre-health professions and is where most pre-health professionals get their foundational knowledge of the human body.

**Methods**

**Study Population**

This survey was conducted at a two-year, open-access college located in the Midwestern United States of America. The college serves approximately 6,000 undergraduate students who complete the first two years of their undergraduate degrees at the college before transitioning to other campuses. Undergraduate students who were enrolled in Anatomy and Physiology I (A&P I) during the Fall 2016 semester were used as the study population. Students generally take this course to fulfill requirements for various allied health programs at the college, such as nursing, dental hygiene, and radiologic technology.

**Data Collection**

Anonymous online surveys were distributed to students enrolled in the course during the first two weeks of the semester via a link posted to either their online course management system (Blackboard) or sent to students directly via their campus email address. To encourage participation and honesty in answering the survey questions, students were informed that their participation in the survey was completely voluntary, that their identities would not be disclosed, and that participation would not influence their grade in any way. To ensure anonymity, the survey was designed to dissuade students from providing identifying information such as student numbers, and email addresses. All participants agreed with the terms of participation prior to completing the survey. The survey was intended to take approximately fifteen minutes to complete under normal circumstances. While completing the survey, students were allowed to skip questions that they chose not to answer and withdraw from participation in the study at any time.

The Institutional Review Board of the University of Cincinnati approved the study (Study ID 2016-1084) as exempt from IRB oversight. Informed consent was obtained from all participants.

**Survey Design**

The survey was designed to include two major parts. The first part included Likert-scale questions to gauge student perceptions of the importance of evolutionary knowledge for the medical field and their opinions on learning evolution while taking Anatomy and Physiology. Likert-scale questions asked students to rate their opinions using the following scale: strongly disagree, disagree, neither agree nor disagree, agree, or strongly agree. The second part of the survey included open-response questions allowing students to demonstrate their understanding of evolutionary concepts and provide rationale for their answers to Likert-scale questions. Table 1 shows the questions asked in the survey.
Table 1. Survey Questions Asked to Respondents

<table>
<thead>
<tr>
<th>Rational for Question</th>
<th>Survey Question</th>
<th>Type of Question</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics &amp; Student Background</td>
<td>Q1: Prior to this class, have you taken a college-level human anatomy &amp; physiology class?</td>
<td>Yes/No</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Q2: Prior to this class, have you previously taken a human anatomy &amp; physiology course at [name of college]?</td>
<td>Yes/No</td>
<td>36</td>
</tr>
<tr>
<td>Opinions of Importance of Evolution to Human Medicine</td>
<td>Q3: Antibiotic resistance in bacteria is a major human health concern.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q4: Medical professionals (e.g., physicians, nurses, etc.) should understand how bacteria become resistant to antibiotics.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q5: Antiviral resistance in viruses is a major human health concern.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q6: Medical professionals (e.g., physicians, nurses, etc.) should understand how viruses become resistant to antiviral medications.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q7: Biological evolution plays an important role in human health.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q8: Biological evolution plays an important role in human medicine.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q9: Medical professionals (e.g., physicians, nurses, etc.) should understand biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q10: It is important for medical professionals to learn about biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q11: It is important to me that my physician understands biological evolution.</td>
<td>Likert-scale</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Q12: Learning about biological evolution is important for students enrolled in Anatomy &amp; Physiology.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q13: Students attending medical school should be required to study biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q14: Students pursuing a nursing degree should be required to study biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q15: Students taking Anatomy &amp; Physiology should be taught about biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q16: Human anatomy is influenced by biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q17: Human physiology is influenced by biological evolution.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q18: Studying human anatomy from an evolutionary perspective would help me learn the topic better.</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Q19: Studying human physiology from an evolutionary perspective would help me learn the topic better</td>
<td>Likert-scale</td>
<td>33</td>
</tr>
<tr>
<td>Testing Understanding of Biological Evolution &amp; Explaining Opinions</td>
<td>Q20: In one or two sentences, please define the term “Biological Evolution.”</td>
<td>Open Response</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Q21: Please explain how bacteria become resistant to antibiotics.</td>
<td>Open Response</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Q22: Please state why you do or do not believe it is important for medical professionals (e.g., physicians, nurses, etc.) to understand biological evolution.</td>
<td>Open Response</td>
<td>26</td>
</tr>
</tbody>
</table>
Data Analysis
The percentage of students responding to each Likert-scale category was plotted for survey questions 3-19. Rubrics were constructed for scoring the open response questions Q20 and Q21 (Table 2). For Q20 and Q21, one point was awarded when a respondent correctly included each of the criteria listed in Table 2. This allowed for the quantification of knowledge on evolutionary processes among respondents. To determine if a relationship existed between student opinions of biological evolution and their knowledge of the subject, correlation analyses were conducted on student scores to open response questions and the opinions they gave to various Likert-scale questions. Student scores for Q20 were correlated to their opinions given in Q9 to analyze the relationship between perceived importance of medical professionals understanding biological evolution and student knowledge of biological evolution. Student scores for Q21 were correlated to their opinions given in Q4 to analyze the relationship between their perceived importance of medical professionals understanding the causes of antibiotic resistance and their ability to explain how bacteria become resistant to antibiotics. To conduct these analyses, Likert-scale opinions were first translated into numerical scores using the following scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. These numerical scores were then correlated to the numerical scores earned by respondents for Q20 and Q21.

Results
A total of 36 students completed the survey during the first two weeks of the Fall 2016 semester. Table 1 shows the number of students that answered each survey question. Of the 36 total respondents, 12 had previously taken an Anatomy & Physiology course before, but only one had taken that course at the college at which this survey was conducted.

The results show that the majority of students surveyed believe that antibiotic and antiviral resistance represents a major human health concern and that medical professionals should understand how these resistances arise. The vast majority of students surveyed believed that antibiotic resistance is a major human health concern (64% strongly agree, 33% agree) and that medical professionals should understand how bacteria become resistant to antibiotics (61% strongly agree, 36% agree). To a lesser extent, students believed that antiviral resistance is a major human health concern (42% strongly agree, 36% agree) and that medical professionals should understand how viruses become resistant to antiviral medications (52% strongly agree, 36% agree).

Responses to survey questions regarding the importance of biological evolution in the field of human medicine showed that students viewed the concept of biological evolution as important. Forty-eight percent of students surveyed stated they agreed (21% strongly agree, 27% agree) that human anatomy is influenced by biological evolution, with no students disagreeing at any response level. Fifty-four percent of students stated they agreed (24% strongly agree, 30% agree) that human physiology is influenced by biological evolution, with only 3% disagreeing.

The vast majority of students believed that biological evolution plays an important role in human health (21% strongly agree, 64% agree) and human medicine (27% strongly agree, 52% agree). Collectively, 85% of students believed that medical professionals should understand biological evolution, with no students disagreeing at any response level. Concomitantly, 85% of students believed that it is important for medical professionals to learn about biological evolution. Perhaps most telling, 84% of respondents agreed that it was important for their personal physician to understand biological evolution.

Interestingly, although the vast majority of students agreed that biological evolution is important to human medicine, there was less agreement with the necessity of medical and nursing students to learn the topic. Although 63% of respondents agreed (24% strongly agree, 39% agree) that learning biological evolution is important for Anatomy & Physiology students, 30% of respondents had no opinion and 6% disagreed with the statement.

Table 2. Rubric for Scoring Open-Response Questions

<table>
<thead>
<tr>
<th>Q20: In one or two sentences, please define the term “Biological Evolution.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>One point was awarded to answers for stating each of the following criteria:</td>
</tr>
<tr>
<td>1. Biological evolution can lead to changes in structure or function of a biological trait (phenotype).</td>
</tr>
<tr>
<td>2. Biological evolution is a genetic process (e.g., changes in allele frequencies).</td>
</tr>
<tr>
<td>3. Biological evolution occurs over successive generations and/or generational time.</td>
</tr>
<tr>
<td>4. Evolved traits are heritable (passed from parent to offspring).</td>
</tr>
<tr>
<td>5. Biological evolution occurs at the population level.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q21: Please explain how bacteria become resistant to antibiotics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>One point was awarded to answers for stating each of the following criteria:</td>
</tr>
<tr>
<td>1. Antibiotic resistance is a biological trait or phenotype.</td>
</tr>
<tr>
<td>2. Antibiotic resistance arises from genetic mutation.</td>
</tr>
<tr>
<td>3. Antibiotic resistance is the result of biological evolution or adaptation.</td>
</tr>
<tr>
<td>4. Antibiotic-resistant cells survive exposure to antibiotics while non-resistant cells are killed.</td>
</tr>
<tr>
<td>5. Cells that survive the antibiotic exposure pass on their genes to next generation.</td>
</tr>
</tbody>
</table>

continued on next page
63% of students agreed (21% strongly agree, 42% agree) that students taking Anatomy & Physiology should be taught about biological evolution, while 9% disagreed (6% disagree, 3% disagree strongly). Sixty percent of students believed that medical schools should require medical students to study biological evolution (27% strongly agree, 33% agree), while 33% had no opinion and 6% disagreed.

Similar opinions were shown when students were asked if nursing students should be required to learn biological evolution (18% strongly agree, 39% agree, 12% disagree). Roughly half of students agreed that studying human anatomy (51%) and human physiology (48%) from an evolutionary perspective would help them learn the topics better, while a much smaller percentage (12% and 15%, respectively) disagreed.

Open response questions revealed that survey respondents had a poor overall understanding of biological evolution and its impact on the emergence of antibiotic resistance (Figure 2). When defining “Biological Evolution” respondents scored an average of 1.46/5 (SD = 1.24) and a median score of 1/5 (25% percentile = 0.75, 75% percentile = 2). Many students stated they did not know how to define the term “Biological Evolution”. When asked to explain how bacteria become resistant to antibiotics, respondents scored an average of 1.04/5 (SD = 1.43) and a median score of 1/5 (25% percentile = 0, 75% percentile = 1). Many of the students did not mention biological evolution in their answers to this question.

Overall, students showed a weak correlation between the opinions they provided of evolutionary topics on Likert-scale questions and their knowledge of evolutionary topics. Although many students responded that they agreed or strongly agreed with the statement “Medical professionals should understand biological evolution”, there was a weak correlation between opinion and ability to successfully define biological evolution ($r^2 = 0.242$). Additionally, while many students agreed or strongly agreed with the statement “Medical professionals should understand how bacteria become resistant to antibiotics”, there was a weak correlation between opinion and ability to explain how bacteria become resistant to antibiotics ($r^2 = 0.166$).

**Discussion**

The data garnered from the survey administered in this study elucidate three important principles. First, anatomy and physiology students viewed evolution-based topics in human medicine as major human health concerns that need further attention from medical professionals. As future medical professionals, these students recognize the importance of these topics, and are, in many ways, the only people who can succeed in counteracting these phenomena. Second, a large percentage of anatomy and physiology students agreed that biological evolution has had important implications for human anatomy and physiology and that learning evolution would help further their knowledge of human anatomy and physiology. This result was somewhat unexpected given the pervasive resistance that the field of human medicine has had to incorporating evolutionary concepts.

**Figure 1.** Responses to Likert-Scale Survey Questions. The percentages of students responding in category is shown. N=33 students for all questions except Q11 N=32.

**Figure 2.** Scores on open-response survey questions. Both questions were scored out of 5 total points using a pre-determined grading rubric. “+” depicts mean. N=26.
Finally, the survey shows that many of the A&P students surveyed lacked a fundamental understanding of the processes involved in biological evolution. Thus, the take home message is that the students surveyed believe that biological evolution is an important topic for medical professionals to learn, but have a very poor understanding of the processes involved. These results may be the result of the lack of educational emphasis for this student population to learn evolution.

Biological evolution remains a controversial topic for many students and instructors (Herman 2013) and it is common to encounter some resistance to learning biological evolution. Additionally, it is common for students to carry their misconceptions about biological evolution into class and for students to retain these misconceptions despite the best efforts of their teachers. Tran et al. (2014) showed that even upper-level biology majors struggle with evolutionary concepts and misconceptions but that discussion of evolutionary concepts helps alleviate these misconceptions. Despite the potential controversy and difficult teaching evolution to undergraduates, the importance of transferring this knowledge to allied health students remains paramount to avoid a future of avoidable medical conundrums such as the increased prevalence of antibiotic resistance.

One of the major challenges that instructors may face is picking appropriate topics in anatomy and physiology in which to integrate evolutionary concepts. However, over the course of the two semesters of anatomy and physiology that most allied health majors are required to take, there are numerous avenues for instructors to interject evolutionary concepts. For example, when discussing the skeletal system, instructors could discuss the structural differences between the anatomy of the lower extremities and pelvic girdle in humans compared to quadruped animals, which is a reflection of the anatomical changes needed to accommodate bipedal locomotion. When discussing the structure and function of the human brain, evolutionary comparisons could be drawn among various primates and mammals to elucidate that human evolution has led to the enlargement of the cerebral cortex relative to body mass, which has permitted increased intelligence and tool use in humans that are not observed in non-human mammals. The number of examples that can be used to elucidate the effects of biological evolution on human anatomy and physiology are plentiful and do not need to occupy a large portion of the course to be effective.

A thorough understanding of biological evolution is fundamental to the study of all fields of biology, including human medicine. By deemphasizing the importance of biological evolution when teaching human anatomy and physiology, students pursuing degrees in health professions are put at a major disadvantage and the effects of an ill-prepared workforce can be felt in the quality of health care services. More attention should be given to teaching biological evolution and correcting misconceptions in foundational courses like anatomy and physiology in order to set students up for lifelong success and prevent avoidable health crises, such as the development of antibiotic-resistant bacteria.

About the Author
Mark Tran, PhD is an Assistant Professor of Biology at the University of Cincinnati Blue Ash College. He teaches Human Anatomy & Physiology and Introductory Biology courses.

Literature Cited
Utilizing Modular Labs in Human Anatomy and Physiology: Lessons Learned From a First Time Experience

Jennifer R. Zitzner, PhD
Loyola University Chicago, 1032 W. Sheridan Rd, Chicago, IL 60660
jzitzner@luc.edu

Abstract
Anatomy and physiology laboratory experiences build upon concepts that are presented in the lecture part of the course. Our anatomy and physiology laboratory class meets weekly for approximately three hours and includes a compilation of activities that are to be completed during the laboratory period. While exercises are built off of topics presented in lecture and predominantly hands-on in nature, many students were not taking advantage of the self-directed learning experiences, especially those employing anatomical models. Some students were content to simply take photographs of models with their cell phones and complete only the graded portions of the laboratory assignment sheets. This behavior was not conducive to mastering the required anatomical details. To provide an enhanced learning environment, we reorganized the laboratory course and the lab manual into modules with the goal of creating a more focused laboratory experience. This article discusses the advantages and hurdles we experienced in the first year of a redesigned modular laboratory experience. doi: 10.21692/haps.2017.029

Key Words: laboratory modules, anatomy, physiology, undergraduate education

Introduction
Technology in the scientific laboratory allows instructors and students to experience anatomical and physiological concepts through realistic, hands-on demonstrations. However, student technology can also inhibit active learning by allowing students to take shortcuts in participation. For example, the use of cell phones or other camera devices in the laboratory allows students to quickly exit the laboratory without the more in-depth, hands-on learning experience envisioned and expected by the laboratory instructors. Aside from the distractions that student technologies can create, the photographic representations of anatomical structures, whether taken by the student, found on the Internet, or appearing in their textbooks, are flat, two-dimensional representations of three-dimensional structures. This poses a serious problem especially when identifying anatomical openings or overlying structures. Another challenge to our long-standing laboratory procedures has been that many students rush to complete the graded assignment sheets without completing and reviewing all of the activities that are included in the laboratory manual.

We presented our concerns at the Central Regional Human Anatomy and Physiology Society (HAPS) conference in November 2015 and found several instructors who struggled with the same challenges we faced in our laboratory. While many methods of improving laboratory instruction were discussed, ranging from prohibiting or limiting external electronic devices to moving to online systems for anatomical structures, we decided to explore presenting the material in modules, where the students would rotate through exercises of a particular concept or system. This would allow us to lead the students through the information in a more guided way and allow the students to focus their attention for a specific period of time on one area of content. We envisioned this would lead to an enhanced learning environment and an improved process of learning.

Inspired by our colleagues and the literature (Ganguly 2010, Miller SA et al. 2002), we set forth to design the modules in our laboratory manual. When thinking of a modular laboratory, we needed to define how we would create our modules. Modular laboratories have been used in several areas of science (Caprette et al. 2005, Chaplin 2003, Howard and Miskowski 2005) and medicine (Ferguson et al. 2013, Gahutu 2010, Zehr et al. 1996). Many modular designs were implemented in order to reinforce learning the scientific method and a single module might last for several weeks. We defined our modules as multiple related groups of information presented during a single laboratory session with the goal of creating a more focused and guided experience for our students. Specifically, the six laboratory tables in our lab space were designed to house either six different modules or two sets of three modules, through which students would rotate during the lab period.

In academic year 2016-2017, we reorganized the lab exercises used in previous years and into guided modules, which replaced the typical lists of anatomical structures and physiological concepts that should be mastered in the laboratory period. The goal of this project was to guide the students through anatomical and physiological concepts over a series of weeks implementing multiple exercises. We hoped that this method would improve the learning experience and possibly increase student retention of the material. Over the course of the academic year, we quantitatively compared laboratory practical examination
scores to those of the previous year (non-modular format) and qualitatively analyzed student and instructor feedback in order to determine if modular laboratories led to increased understanding and student retention.

The intention of the laboratory change was to provide students with a focused subset of information before moving on to a related module. Although each week’s modules explored similar topics or systems, different pedagogical methods were employed for each module. Pedagogical methods included the use of anatomical models, histological slides, anatomical dissection, computer simulations, and case studies. We anticipated that students would benefit from being directed to stay at each module for a specific period of time instead of being allowed to quickly progress through the modules at their own pace and completing only the graded work. Our expectation was that changing the methodology of the laboratory would serve to prepare students for further educational endeavors including upper-level courses and professional schools such as medical schools and advanced degree nursing schools.

**Student Population and Design of Modules**

At Loyola University Chicago, the human anatomy and physiology lab serves two populations of students. One student population consists of biology majors who typically take the course as undergraduate juniors and seniors. The second student population consists of allied health majors who are typically freshman nursing students or sophomore and junior exercise science majors. Students at both levels have approximately three hours of lecture and a three-hour lab per week. The number of students enrolled in the anatomy and physiology labs during the two years compared in the study is shown in Table 1. The laboratory manual and materials are similar for both student populations but the expectation of learning and retention and the level of difficulty on the laboratory practical exams are greater in the biology majors course.

<table>
<thead>
<tr>
<th>Year</th>
<th>Semester</th>
<th>Allied Health</th>
<th>Biology Majors</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015-2016</td>
<td>Fall</td>
<td>201</td>
<td>239</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>180</td>
<td>157</td>
</tr>
<tr>
<td>2016-2017</td>
<td>Fall</td>
<td>230</td>
<td>215</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>205</td>
<td>152</td>
</tr>
</tbody>
</table>

Table 1. Enrollment totals for the two years compared in the study. During the 2015-2016 year laboratory exercises were presented as a list for the students to work through. During the 2016-2017 year laboratory exercises were presented in modules when appropriate.

Eleven of the eighteen lab exercises presented through the year were amenable to a modular format. The material covered in modular form was the same as that which had been presented the previous year in non-modular form, with the additional material added, if necessary, to make the modules the appropriate length. When setting up the material to be covered in each module, consideration was given to the amount of material and the time needed to complete the exercise. After the instructor provided an introduction and brief description of the modules, students worked on each module in groups of four per table. During the fall semester lab sessions were divided into six modules and students moved between the modules at set twenty-minute intervals. After the feedback from the fall semester, the length of time given for each module was increased to thirty minutes and the number of modules was limited to three per lab. In this case, two sets of the three modules were used. Time was allotted at the end of each laboratory for students to revisit any modules they had not completed or wanted to explore in more detail.

**Data Collection and Feedback Methods**

Quantitative data was used to analyze scores on laboratory practical exams and qualitative assessments, using anonymous surveys, were made of student and instructor feedback. Laboratory practical exam scores for students using the new modular guided laboratory manual were compared to the scores from the previous year when the exercises were non-modular. It is important to note there is some variation in the part time faculty who staff some of the lab sections. Average scores from each laboratory practical exam were gathered and compared for the two academic years covered by the study.

Qualitative data was collected and recorded in survey form. Students and instructors were asked several questions regarding how their perceived or observed understanding of lab concepts changed with the use of the guided modular exercises. Surveys assessing efficiency and retention of information acquired during the laboratory modules were given at the end of the fall semester so that we could improve on the modular arrangement of the laboratory for the spring semester. All data from surveys were anonymous to protect both student and instructor identities. Participation in the surveys was voluntary with no “extra-credit” points given for completing the survey.

This project was approved by the Internal Review Board of Loyola University Chicago’s Office of Research Services and was considered to be under exempt status. Students were made aware of the change in laboratory methodology from the beginning of the semester. The following statement was inserted into the course syllabus:

“At the end of the course, a voluntary survey will be given evaluating the effectiveness of learning and retention using the laboratory modules. No results from these surveys will be viewed until all final grades are given and results will not affect in any way the outcome of your overall grade.”

continued on next page
A verbal description of the change in methodology was also given on the first day of class.

**Quantitative analysis of laboratory practical scores**
The laboratory exercises and practical exams were scheduled as in previous years. Three laboratory sessions were followed by a laboratory practical exam. Therefore, each semester provided three quantitative measures. No student identifying information was recorded. The data was divided into two groups (allied health majors and biology majors) to make comparable measurements. The quantitative scores for each practical are summarized in Figure 1.

As shown by the comparison of the two consecutive years with different laboratory content delivery methods, there was no measurable difference in laboratory practical exam scores between the two years. Feedback from instructors and students was also analyzed.

**Student Feedback**
Student surveys consisted of two components: statements that were rated from strongly agree to strongly disagree and two free response questions. The rated survey statements are presented in Table 2. Since surveys were voluntary, not all students completed surveys and the number of student responses is noted in the table. Overall, student responses from the two subsets of students were very similar and highlighted that the modular laboratory format was helpful in focusing student attention on the material as well as keeping students on track. Both groups found that the modular laboratory helped students work together as a team and provided an effective learning environment.

While the responses to statements showed a positive experience with the modular laboratory format, the free response questions showed areas where improvements could be made. Two free response questions were asked:

1) In your own words, did you find learning the laboratory material in modules rather than a list of activities effective?
2) Please offer any suggestions to improve the laboratory modules. (What worked and what did not work?)

Student comments to the free response questions varied however, two major themes emerged. The first theme was that the modular format provided a guided experience in the laboratory. While the students did not have the experience of previous years to compare (no control group was employed in this analysis), the majority of students found the delivery of the material to be effective. However, the overwhelming criticism was that the modules were either too short or too long for the prescribed amount of time before rotating to the next module. For modules that were considered too short because of lack of activities or working speed of the group, the students had to wait for time to rotate. Students felt rushed if they had not completed the exercise material in the allotted time. Time was allocated at the end of the laboratory for students to return to any module they had not completed but most students did not utilize this opportunity. Students also commented that they preferred to work at their own pace or to work individually rather than in a group. Neither of these choices conforms to the delivery of modular content we designed.

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**Figure 1.** Average laboratory practical exam scores with modular laboratory exercises (2016-2017; black bars) compared to the previous year with a non-modular laboratory manual (2015-2016; grey bars). A) Average practical exam scores for allied health majors. B) Average practical exam scores for biology majors. The bars for both graphs represent the standard deviation.
Instructor Feedback

Instructors were asked to provide feedback on the modular laboratory format. All surveys were voluntary and no instructor identification information was recorded on the surveys. The statements and responses from the instructor survey are listed in Table 3.

Responses indicated that the modular laboratory format was generally a positive experience for the instructor. Instructors noted that students were not always satisfied with the format, which corresponds to the comments listed above. Overall, the instructors generally agreed that the laboratory modules were an effective and efficient way to deliver the material each week.

Instructors were also given two free response questions to give additional comments on their experience in the laboratory. The questions were:

1) In your own words, did you find student learning of the laboratory material in modules rather than as a list of activities effective?
2) Please offer any suggestions to improve the laboratory modules (What worked and what did not work?)

Instructors commented that the modules helped divide the material into manageable amounts that kept the students focused on the task and on track during the laboratory. Instructors indicated that the most significant pitfall was when the students finished a module early or perceived that they did not have enough time to finish a module before moving on to the next. This corresponds to the information gathered from student surveys.

Discussion

The anatomy and physiology laboratory is designed to complement the content that is provided in the lecture portion of the course. While our laboratory instructors were satisfied with the activities performed in the laboratory, we were discouraged by the shortcuts and perceived learning that was occurring as a result of student technology and lack of focus on the activities provided. Therefore, we set forth to change the method of delivery of our laboratory exercises and activities to allow students to focus on smaller portions of the material at one time and to require students to move through each exercise on a prescribed time schedule.

Instructor Survey Responses (n=10)

<table>
<thead>
<tr>
<th>Instructor Survey Responses (n=10)</th>
<th>Strongly Disagree (1) -&gt; Strongly agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>The modular laboratory sessions helped keep students on track and focused on the laboratory material</td>
<td>0%</td>
</tr>
<tr>
<td>The laboratory modules provided an effective learning environment</td>
<td>0%</td>
</tr>
<tr>
<td>The laboratory modules provided increased student learning and retention of material</td>
<td>0%</td>
</tr>
<tr>
<td>Students enjoyed working in laboratory modules</td>
<td>0%</td>
</tr>
<tr>
<td>As an instructor, the laboratory modules helped deliver the laboratory more effectively/efficiently</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 3. Voluntary instructor survey responses evaluating the modular laboratory format. Values are percentages relative to the total number of participants.
After quantitatively examining the practical exam scores between the years using a standard manual versus a modular format, we saw no measurable difference in scores. While we did expect that scores would increase with the modular format, the goal of the change in laboratory format was to help students learn the material and to avoid perceptions that the information was best understood by simply taking pictures of models or by completing only the pages of the manual that would be graded.

Student and instructor responses indicated that the goal of organizing the laboratory exercises in a more manageable and focused way through modules did prove to be effective. However, the most frequently listed comment for improvement, from both instructors and students, was the length of time spent at a module and amount of content at each module. To address this, when setting up the laboratory modules, it is important to think about the diversity in the student population, especially in terms of educational background. Students with a more extensive background in science may work at a faster pace, as some of the concepts may already be understood. However, if students do not have a solid science background, as is the case for many of our allied health students, more time may be needed to fully grasp the concepts presented.

Although our biggest challenges during the first year were inconsistencies in content quantity and time allotted per module, the modules can be modified for the following years. For example, comments from students after their first semester indicated that more time was needed at some modules, and the logistics of moving between six modules was more disruptive than we had imagined. Therefore, we altered the second semester to contain duplicate sets of three, longer modules. The potential problem with this change is the availability of resources in the lab (specimens, anatomical models, histological slides, etc.)

We also found that student perceptions of the laboratory experience seemed to vary according to the laboratory section. This led us to believe that some lab instructors may have influenced student perceptions. If there are multiple sections of the laboratory course, it is important that all instructors agree on how the modules should be presented and a discussion of best practices for helping the students maximize the experience at each module is vital.

Conclusion
The goal of our project was to assess the effectiveness of using modular laboratory exercises in the anatomy and physiology laboratory at Loyola University Chicago. We aimed to assess whether changes to our laboratory methods improve the effectiveness of learning in our laboratory. While the delivery of the material as modules changed between the two years analyzed, the content remained very similar; therefore, we aimed to assess only the delivery and teaching methods in this study.

While the overall feedback was positive, there were some hurdles that any laboratory may experience when trying a new delivery model. Although the quantitative practical exam scores did not differ, both students and instructors felt the laboratory allowed students to focus on smaller portions of material and stay on track throughout the laboratory session. However, careful planning needs to take into consideration the amount of time and content per module. Assessing the needs and background of student population and explaining the purpose of the modular setup will help identify the expectations for the laboratory experience.

About the Author
Jennifer R. Zitzner is an advanced lecturer in the Department of Biology at Loyola University Chicago. She teaches undergraduate human anatomy and physiology for biology majors and allied health majors and is interested in incorporating pedagogical techniques for lecture and laboratory settings that improve engaged learning and retention for students.

Acknowledgements
I would like to acknowledge and thank Drs. Patrick Duffie and Robert Morgan for their contributions to the modular lab manual and the collection of quantitative data and editing of this manuscript. Their experience, advice, and help in debating the best pedagogy for the laboratory sections shaped the lab manual each semester. I would also like to thank all of the laboratory instructors who gave feedback each week and helped to make the modular laboratory project a positive experience.

Literature cited


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Visual? We’ve Got You Covered: An In-House Anatomy Atlas Improves Students Learning

Jennifer Hutchinson BSc, BScN, RN¹, Rex Thangarajah PCP, AEC, Med Tech¹, Hilary Hough GD, Hisham S. Elbatarny MB BCh, MSc, MD¹,²
¹School of Baccalaureate Nursing, St. Lawrence College, 100 Portsmouth Avenue, Kingston, ON, K7L 5A6, Canada.
²Department of Biomedical and Molecular Sciences, Queen’s University, Kingston, ON, Canada.
JHutchinson@sl.on.ca, RThangarajah12@student.sl.on.ca, hilaryh94@gmail.com, HElbatarny@sl.on.ca, (corresponding author)

Abstract
Fortifying anatomy course materials with visual aids is undoubtedly beneficial to the learning process. The aim of this project was to develop an in-house gross anatomy atlas and investigate its role in improving student performance in the gross anatomy component of a first-year anatomy and physiology course for BScN students at St. Lawrence College. The atlas was developed using local anatomy specimens such as preserved cadavers and models. Images of captured specimens were edited, labelled, and converted into a printable format. The atlas was made available to the students. The efficacy of this atlas was analyzed by comparing test scores of the class of 2015 (atlas not available) to the class of 2016 (atlas provided). The class of 2016 significantly outperformed that of 2015 on gross anatomy-focused quizzes (p<0.05). We found that addition of an in-house gross anatomy atlas improved student performance in the laboratory and enhanced overall anatomy learning. doi: 10.21692/haps.2017.030

Key Words: nursing, atlas, laboratory, anatomy, physiology

Introduction
The instruction of anatomy and physiology in the post-secondary nursing curriculum has been universally challenging (Davis 2010, McVicar and Clancy 2001, Jordan et al. 1999). Many nursing students describe difficulty in understanding the key concepts covered in anatomy and physiology courses (Birks et al. 2013). This can be in part attributed to a well-documented malalignment between the teaching methods and the learning styles of many of the students who chose nursing programs (Johnston et al. 2015). Research into the best approach for delivering bioscience content in nursing programs is ongoing. It has been suggested that a mixed-mode approach to instruction, where a combination of digital technologies, face-to-face teaching, and hands-on activities are used to enhance learning, is often a good strategy (Eagleton 2017, Heffernan 2012, Salvage-Jones et al. 2016).

In line with this multi-faceted approach to content delivery, we previously demonstrated that the incorporation of an in-house histology atlas into the laboratory component of Human Anatomy and Physiology (LUSL 2105), improved student performance on histology focused tests (Elbatarny et al. 2015, Hutchinson and Elbatarny 2016). Using a similar approach, we developed an in-house printed gross anatomy atlas, enabling students to study exact gross anatomy laboratory specimens beyond their 3-hour weekly lab session.

Methods
This study was conducted in the anatomy laboratory at St. Lawrence College in Kingston, Ontario. Creation of the atlas involved developing an inventory of all gross anatomy specimens utilized in the instruction of LUSL 2105, a human anatomy and physiology course required for first-year students in bachelor of science in nursing (BScN). The process included the organization of specimens into organ systems. All specimens were then photographed from various angles using a high quality digital camera to capture all relevant anatomical structures. The images were appropriately edited using Adobe Photoshop™ software, which included background removal for improved clarity. Each specimen was thoroughly labelled (Figure 1). Labelling was guided by the Human Anatomy and Physiology (LUSL 2105) laboratory syllabus to ensure that content was appropriate for the course level. All images were digitally transcribed by the graphic designer using InDesign™ software. The digital transcription included labelling, editing, formatting and color conversion to change the image into a printable format. Images were then thoroughly revised and approved prior to final printing. A snapshot of a page of the completed atlas is shown in Figure 2. This atlas was made available to LUSL 2105 students enrolled in September 2016.

Anonymized laboratory test scores were recruited from BScN students enrolled in 2015 (n=65) and 2016 (n=88). Content and testing remained consistent between both groups, however the class of 2016 had access to the newly developed gross anatomy atlas while the class of 2015 did not. Scores on quizzes containing gross anatomy content exclusively were statistically compared between classes to analyze the effect of the atlas on course performance. Overall lab performance was also statistically compared.
Figure 1: Gross anatomy specimens are saved and labeled according to course relevant anatomical structures.

Figure 1A: before labeling

Figure 1B: after labeling

Figure 2: A representative snapshot of one of the pages of the completed atlas illustrating the digital transcription: color conversion, editing, formatting and labeling using InDesign software.
Results
Comparison of gross anatomy focused lab quiz performance revealed that the class of 2016 (70.9%) significantly outperformed the class of 2015 (63.5%) (p<0.001) (Figure 3). Analysis of overall lab quiz performance revealed that the class of 2016 (77.6%) generally performed better than the 2015 class (73.1) on most of tested components of the anatomy lab which indicated that the class of 2016 was academically stronger (Figure 4). Taking this difference into consideration and normalizing the atlas based test results, the analysis revealed that class of 2016 still significantly outperformed the class of 2015 in the anatomy atlas-based tests (p<0.05).

Figure 3: Mean gross anatomy focused quiz scores for the class of 2015 and 2016.

Figure 4: Overall lab quiz scores for the class of 2015 and 2016

Discussion
When compared against other content presented in first year baccalaureate nursing programs, performance in anatomy and physiology is the strongest predictor of success in future clinical nursing courses (Brown et al. 2017). It is also recognized that emphasis on anatomy and physiology in the nursing curriculum facilitates safe and effective point-of-care assessment (McVicar et al. 2010). However, as a result of poor student performance in bioscience courses, there has been an internationally documented reduction in the delivery of this content, with many nursing programs failing to facilitate industry required knowledge levels (McVicar et al. 2014). Our previous experience showed that fortifying the histology lab by adding an in-house histology atlas significantly enhanced student performance and learning (Hutchinson and Elbatarny 2016), which inspired us to take a similar approach in the gross anatomy section. We found this approach quite helpful especially for the visual learners. The improvement in student performance that we observed with the addition of this in-house gross anatomy atlas suggests that similar approaches may be a feasible way to remedy this shortcoming in nursing education. Furthermore, Dobson et al. (2015) demonstrated that self-testing among university students in anatomy and physiology produced superior recall of anatomical structures, a practice that is enabled by the created atlas.

Research also indicates that the instruction of anatomy and physiology can be improved by the incorporation of digital technologies (Eagleton 2017, Shoepe et al. 2014). The potential exists to further develop this in-house gross anatomy atlas into an online tool, with more interactive learning activities. This approach may help further bridge the gap that currently exists in the presentation of anatomy and physiology in nursing programs (Johnston et al. 2015).

About the Authors
Dr. Elbatarny is a consultant internist who received his medical training in Egypt. His research interest is in cardiovascular biology. He is a professor and tri-campus science lead at the School of Baccalaureate Nursing at St. Lawrence College, Kingston, Ontario, Canada where he teaches Human Anatomy & Physiology and Clinical Chemistry to BScN students. He is also an adjunct associate professor at Queen’s University where he participates in teaching Pharmacology, Pathophysiology, and Anatomy. He is the founder of the Anatomy Museum at St. Lawrence College. Dr. Elbatarny has over 20-years of experience in medical practice, research, and teaching in Egypt, Kuwait, the UK, and Canada.

Jennifer Hutchinson graduated with honors from Queen’s University in 2012 with a BSc in Biology. In 2015 she received her BScN degree from St. Lawrence College / Laurentian University. Jennifer is the recipient of the St Lawrence College Dean’s List award for top academic achievement by an individual in the BScN program. Since graduating she has been working as an RN in the emergency department at Kingston General Hospital, a large tertiary care center. She also works as a lab technician in the molecular lab at SLC, teaching anatomy and physiology to first year BScN students.

Rex Thangarajah is currently a third year student in the Laurentian University BScN program at St. Lawrence College, Kingston. He completed primary care and advanced
emergent care paramedic programs and worked with the Canadian Armed Forces as a medical technician for six years. He is also a peer-tutor in anatomy and physiology and clinical chemistry courses. Besides studies, he trains in karate, plays guitar, and travels on his motorcycle.

**Literature cited**


What, How, and Why: Writing Interview-based Cases Helps Students Connect Anatomy and Physiology Concepts to Real Life

Tracy L. Ediger, PhD
Georgia Gwinnett College, 1000 University Center Lane, Lawrenceville, GA 30043
tediger@ggc.edu

Abstract
This article describes an interview-based project that helps students connect anatomy and physiology to pathology and practice their skills in data interpretation and the review of scientific literature. In this project each student identifies a family member or friend to interview about his or her personal experience with a specific disease. Topics are approved by the instructor based on appropriate scope and relevance to one of the seven organ systems studied in the second-semester of an anatomy and physiology course. Students use the interview to construct a narrative with embedded questions that is then presented to the class as a way to review for the final exam. doi: 10.21692/haps.2017.031

Key Words: case study, student research, data interpretation, interview

Introduction
Anatomy and Physiology is a content-rich course intended to teach the fundamental concepts of human anatomy and physiology that are required for entry into health care professions such as nursing. Some students may find the quantity of information presented in the course to be overwhelming. Consequently, these students may struggle to maintain the focus and intensity required to succeed over the course of the semester. In addition, as instructors we want our students to reach past the memorization of anatomic structures to a deeper understanding of the processes of human physiology.

Writing a case study based on the experience of a friend or family member allows a student to connect textbook knowledge with real-world experience. Students often ask questions in class that are related to the medical problems of friends or family members. When given a choice of topics to research for a class project, students often choose a topic that impacts someone they know. In this assignment, students are encouraged to research a topic of personal interest, which enhances student engagement and motivation.

Data interpretation and quantitative reasoning are skills essential to the practice of health care. These same skills are also helpful for any patient or patient advocate interacting with a health care professional. Thinking through the process of data collection and interpretation required to diagnose a medical problem allows the application of quantitative reasoning skills to a specific situation. Skills of written and oral communication are also important to our students’ educational foundation. This project provides an arena in which to practice those skills, and in so doing, allows each student to share new knowledge with the larger group.

The case study project constituted Course-Related Research conducted by students. The Institutional Review Board of Georgia Gwinnett College approved this study under IRB #16005, as a Course-Related Exempt Study. Student perspective on the project was solicited under a separate IRB number, #15277, which concerns Evaluation of the Anatomy and Physiology Classroom related to the study of the flipped classroom.

Assignment
Biology 2452K (A&P2) is an integrated lab and lecture course offered at Georgia Gwinnett College, the second course in a two-semester sequence of anatomy and physiology. This course meets for two hours and forty-five minutes twice weekly for fifteen weeks. The maximum enrollment is twenty-four students per section. During the Fall 2016 and Spring 2017 semesters, students were assigned to write a case study as their semester project.

The assignment was implemented progressively. Table 1 lists the sections assigned, grouped according to successive deadlines. Sections submitted together are listed together. Instructor approval was required at several points prior to the student continuing with the project. Sections were assigned as follows:

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Table 1. Sections of the Assignment

<table>
<thead>
<tr>
<th>Section</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic</td>
<td>Submit at least one idea.</td>
</tr>
<tr>
<td>Background and Interview Questions</td>
<td>Collect information and structure background section according to the formatting directions. Use appropriate references. Submit a list of at least 10 questions to ask during the interview.</td>
</tr>
<tr>
<td>Interview, Narrative, Q&amp;A</td>
<td>Conduct the interview. Using this information, create a narrative. Intersperse questions to ask your listeners when you present the narrative, as well as the answers you would expect.</td>
</tr>
<tr>
<td>Scientific Inquiry Q&amp;A</td>
<td>Write 3 questions. Find at least 2 scientific research articles that respond to these questions. Summarize the data in these articles and explain how this helps to answer your questions.</td>
</tr>
<tr>
<td>Presentation</td>
<td>Use your Narrative and Q&amp;A sections to build a 10-15 minute presentation. Submit your presentation before class.</td>
</tr>
</tbody>
</table>

**Topic:** Each student submitted one, two, or three preferences for a potential interview topic. To be approved, a topic had to be of reasonable scope (neither too broad nor too narrow), and had to represent a problem affecting at least one organ system included in the Anatomy and Physiology 2 course curriculum. An attempt was made during the submission process to achieve a diversity of topics.

**Background:** A fundamental grasp of the essential elements of the clinical condition was demonstrated by writing a background section. The format for the background included the following:

1) A two-sentence summary describing the disease
2) Paragraph 1: a general description of the disease and its cause
3) Paragraph 2: a description of the symptoms of the disease and the diagnosis
4) Paragraph 3: a description of the prognosis and treatment of the disease
5) References. Web-based resources appropriate for laypersons were deemed acceptable as references.

**Interview Questions:** Each student was required to submit a list of at least ten questions to be used during the interview. These questions could range from open-ended ("Tell me what happened.") to more specific questions based on features of the particular disease.
**Student Response**

Topics chosen by students are shown in Table 2. During the four courses represented here, student topics covered a wide range of medical conditions related to each of the seven organ systems covered in the second semester of anatomy and physiology. Certain topics tended to be over-represented. For example, there were multiple students interested in exploring diabetes mellitus, coronary artery disease, and Hashimoto’s thyroiditis. If students had other options for topics, they were guided toward other choices.

<table>
<thead>
<tr>
<th>Organ System</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endocrine</td>
<td>diabetes mellitus (type I, type II) Hashimoto’s thyroiditis Graves’ disease pancreatic glucagonoma</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>coronary artery disease; hypertension congestive heart failure vasovagal syncope pulmonary arterial hypertension mitral valve prolapse Wolff-Parkinson-White Syndrome cardiac tamponade rectal hemorrhoids</td>
</tr>
<tr>
<td>Lymphatic / Immune</td>
<td>lymphedema HIV infection Hodgkin’s lymphoma systemic lupus erythematosus rheumatoid arthritis</td>
</tr>
<tr>
<td>Respiratory</td>
<td>chronic obstructive pulmonary disease obstructive sleep apnea asthma</td>
</tr>
<tr>
<td>Digestive</td>
<td>Crohn’s disease hepatitis C infection cirrhosis appendicitis gastric ulcer obesity / gastric bypass surgery</td>
</tr>
<tr>
<td>Urinary</td>
<td>chronic kidney failure renal cell carcinoma</td>
</tr>
<tr>
<td>Reproductive</td>
<td>breast cancer polycystic ovary syndrome cervical cancer</td>
</tr>
</tbody>
</table>

**Table 2. Student Topics**

At the end of the semester, students were given a survey covering multiple aspects of the course. Three of the questions were specific to the case study-writing project. These questions and their responses are shown in Figure 1. Questions were formatted as a statement and students could choose whether or not they agreed with the statement by using an associated Likert Scale.

The first statement was, “I found the case study project to be a good way to learn in depth about an A&P topic”. Thirty-three percent of survey respondents Strongly Agreed with this statement and fifty-one percent Agreed (n=49).

The second statement was “I was able to find a topic that was interesting to me personally”. The majority agreed with this statement. Forty-one percent of survey respondents marked Strongly Agree and forty-seven percent marked Agree.

The third statement was “I feel more confident to talk to doctors about myself or my family”. There were zero negative responses to this statement. Ninety-two percent of survey respondents chose either Strongly Agree or Agree.

**Figure 1. Student Survey Responses (n=49)**
Discussion

In content-dense courses such as anatomy and physiology, teachers may continually feel stress about “covering” the material. Continued focus on “getting through” a large quantity of information may prevent students from stepping back to see the bigger picture. This project, assigning students to write a case study based on a real-life situation, allows students to connect real-world experience to their classroom experience. Students have the chance to see how textbook concepts play out in real life. In addition, requiring students to generate additional questions that they then answer by reading the scientific literature will hopefully increase student ability to seek answers to scientific and medical questions by turning to scientific research.

Implementation of this project requires a significant input of instructor time throughout the semester. Students must receive approval for their choice of topic and their background and interview questions prior to conducting the interview. Additional sections of the paper and/or the presentation file may be turned in for feedback prior to final grading. For example, one semester the worksheet of scientific inquiry (with the first page of two scientific papers attached) was turned in for a separate grade prior to the final project grading. Giving feedback on specific sections prior to scoring the final project encourages students to meet high standards.

Students submitted topic selections during the second week of the semester. In this way, an attempt was made to concentrate the work of the project during the first half of the semester. If students worked through the sections as prescribed, they would be finished well before the last week of the semester when presentations were scheduled. These classes were capped at 24 students and some students dropped the course at the midpoint of the semester. Scheduling twenty-some presentations requires a significant investment of time on the part of the instructor. The project was presented to students as a way to help them review all of the organs systems in preparation for the comprehensive final exam. Even though students were encouraged to include a general review of information in their presentation, some students commented on course evaluations that the class time would have been better spent reviewing for the test.

Students turned in all sections of the writing assignment for a final grade. Students were also scored on their presentations. In the process, students had the opportunity to practice written and oral communication skills. Most colleges and universities aim to encourage the development of communication skills. At Georgia Gwinnett College, one college-wide goal is that students “clearly communicate ideas in written and oral form” (Integrated Educational Experience goal #1) and communication is one of the course objectives of Anatomy and Physiology 2. Even though there is a lot of anatomy and physiology course content, it is important to remember course objectives include skill building as well as mastery of knowledge.

The development of “authentic tasks” that bring real life into the classroom can help increase student engagement and motivation. Implementing this type of activity is listed as one of the things that the “best colleges teachers do” (Bain 2011). In anatomy and physiology courses, students often have questions about personal and proximate medical issues. This project allows students to investigate the pathogenesis, prognosis, and treatment of a medical condition of their choice. Most students were able to identify a topic of personal interest. Requiring students to submit topic ideas for approval facilitates discussion of the project plan with the instructor early in the process. To successfully engage students in class projects, it has been suggested that students must see value in the project and they must feel able to complete the task. This is known as the expectancy x value model (Barkley 2010). According to this model, students can see value because the topic is directly connected to course curriculum and the topic is personally relevant. The project format requires frequent formative assessment and feedback from the instructor in an attempt to improve student confidence and performance.

Using this project in my classroom has allowed me to learn from my students. Many of us teach the same course curriculum semester after semester. Creating the opportunity to interact with students about their reading and research can help keep the course new for the instructor as well as for the students.

About the Author

Tracy Ediger is an Assistant Professor of Biology who spends most of her professional time teaching anatomy and physiology and chatting with students about course choices, career plans, and life outside the classroom. In her personal time, Tracy reads, cooks, hikes, and travels.

Literature cited

Call for Papers: *HAPS Educator*: Special Curriculum Issue

Do you have a classroom activity that promotes good conversations among students? Here is your chance to leverage your work into a peer-reviewed publication with a DOI number. We are publishing a special issue of the *HAPS Educator* devoted to curricular materials for the active learning Anatomy, Physiology, or Anatomy and Physiology classroom.

**Submission Guidelines**

The submission must include:

1. Title
2. Contact information
3. Student Activity
4. Teacher’s Guide
   - Target audience
   - Learning outcomes (including relevant HAPS learning outcomes, available [HERE](#))
   - Prior knowledge required
   - Time required
   - Guidelines for classroom implementation
   - Instructor observations (e.g. student conversations during the activity or misconceptions revealed by the activity)
5. Answer Key. The answer key will not be published in the Educator. Instead, answer keys will be made available on a secure, members-only area of the HAPS website.

Two sample activities are available: *Activity 1 Here* and *Activity 2 Here*

**Note:** Submitted activates must not contain any copyrighted materials; all text and images must be original.

**Review Process**

All submissions will be subject to anonymous peer review. Submissions will be evaluated based on the following criteria:

1. Is the activity scientifically accurate?
2. Does it have the potential to effectively promote student conversations?
3. Does it address one or more of the key HAPS learning outcomes?
4. Has the author used the activity in their own and potentially others’ classrooms?

Accepted activities may be copy-edited for grammar and style, but will not be otherwise modified.

**Submission deadline:** September 30, 2017  
**Target date for publication:** November 15, 2017

Questions: Contact Murray Jensen at editor@hapsconnect.org
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<table>
<thead>
<tr>
<th>Committee</th>
<th>Chair/Co-Chairs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANIMAL USE</strong></td>
<td>Mary Vagula</td>
</tr>
<tr>
<td><strong>CADAVER USE</strong></td>
<td>Cindy Wingert</td>
</tr>
<tr>
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</tr>
<tr>
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<td>Tom Lehman</td>
</tr>
<tr>
<td><strong>CURRICULUM AND INSTRUCTION</strong></td>
<td>Christine Canady</td>
</tr>
<tr>
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<tr>
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<tr>
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<td>Peggie Williamson</td>
</tr>
<tr>
<td><strong>HAPS EDUCATOR</strong></td>
<td>Kerry Hull, Chair, Sarah Cooper, Editor-in-Chief</td>
</tr>
<tr>
<td><strong>MEMBERSHIP</strong></td>
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</tr>
<tr>
<td><strong>NOMINATING</strong></td>
<td>Judy Nath, Chair</td>
</tr>
<tr>
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<td>Betsy Ott</td>
</tr>
<tr>
<td><strong>SAFETY</strong></td>
<td>Yuli Kainer, Co-Chair, Neal Schmidt, Co-Chair</td>
</tr>
<tr>
<td><strong>STEERING</strong></td>
<td>Kyla Ross, Chair</td>
</tr>
<tr>
<td><strong>TESTING</strong></td>
<td>Jennifer Burgoon, Valerie O'Loughlin, Co-Chair</td>
</tr>
<tr>
<td><strong>2017 CONFERENCE COORDINATOR</strong></td>
<td>Mark Nielsen</td>
</tr>
</tbody>
</table>

**Click here to visit the HAPS committees webpage.**

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**ANIMAL USE**

Mary Vagula

This committee is charged with developing, reviewing, and recommending policies and position statements on the use of animals in college-level A&P instruction.

**CADAVER USE**

Cindy Wingert

This committee is charged with developing, reviewing, and recommending policies and position statements on the use of cadavers for human anatomy and physiology education in colleges, universities and related institutions.

**COMMUNICATION**

Wendy Riggs, Chair

This committee is tasked with helping HAPS establish its voice in a technological landscape shaped by social media. Committee members work closely with the Marketing Committee to facilitate connections within HAPS as well as recruiting potential members via social media.

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This committee is responsible for publishing a quarterly edition of the HAPS Educator, the journal of the Human Anatomy and Physiology Society. The committee works closely with the Steering Committee and the President of HAPS.

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This committee is charged with expanding our membership base to include all Human Anatomy and Physiology educators or those individuals, institutions and corporations crucial to the HAPS mission statement of “Promoting Excellence in the Teaching of Human Anatomy and Physiology.”

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