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Lecture Capture Technology (LCT): Following some rules and breaking others. The advantages, perks, and pitfalls of LCT implementation in large human anatomy, physiology, and pathophysiology classrooms.

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Abstract
There is much in the literature about the perks and pitfalls of introducing lecture capture technology (LCT) into the classroom, with recommendations and guidelines as well as mixed reports outlining the ensuing expected and unexpected, in terms of positive and negative outcomes. With the goal of providing another student study resource, LCT was introduced into five large anatomy, physiology, and pathophysiology courses at the University of British Columbia Okanagan. Some literature guidelines were followed, including: i) introduce LCT into content-heavy, lecture-based courses, ii) make LCT easy to use for students, iii) make recordings annotated and interesting, and iv) provide enough in-class activity to prevent drops in attendance. Other guidelines were not followed, for example: i) keep videos novel, short, and focussed on problem areas; ii) conduct mid- or post-video tests; and iii) provide to first-years but not upper-years. This paper details LCT’s merits and drawbacks for very different cohorts across three years of an undergraduate program. doi: 10.21692/haps.2018.001

Key words: physiology, lecture capture, student engagement

Introduction
Lecture capture technology (LCT) has become more robust and popular at universities and colleges over the last ten years. In addition, the ability to implement this technology in both large and small classrooms has become more feasible in a variety of different settings. As a result, there has been much study on whether adapting lecture capture (LC) positively affects learning and what best practice should entail. Thus far, studies in the literature have attempted to answer the following questions:

1. Does LC positively affect learning?
2. Is LC an effective substitute for face-to-face lectures?
3. Does LC lead to absenteeism?
4. Which students benefit the most from LC?
5. Do students believe LC is beneficial to their learning?
6. Do faculty believe LC is beneficial to their students’ learning?

1.1 Does LC positively affect learning?
A meta-analysis by Danielson et al. (2014) indicates that results in the literature are mixed. Some studies found that there was no clear relationship between learning outcomes and lecture capture use (Spickard et al. 2002, Solomon et al. 2004, Brotherton and Abowd 2004, Bacro et al. 2010, Franklin et al. 2011). Other studies have reported mixed or negative effects (McNulty et al. 2009, McNulty et al. 2011, Owston et al. 2011, Fernandes et al. 2012). However, positive results have also been reported (Bridge et al. 2009, Dey et al. 2009, von Knosky et al. 2009, Elsasser et al. 2009, Inglis et al. 2011, and Shaw and Molnar 2011).

Specifically in studies with positive outcomes, researchers found that students who both attended face-to-face lectures and devoted time to reviewing LC recordings had higher exam results on average than students who only attended face-to-face lectures, or who only learned material through lecture videos or other resources (e.g. tutorial sessions). Such studies reporting positive outcomes were conducted in a variety of large undergraduate courses and include: Williams et al. 2012 study of a 1st-year Microeconomics Principles class; Wieling and Hofman’s 2010 study of a European Law course, Danielson et al.’s 2014 study of veterinarian classes, and Stockly and Hemley 2017 five-year study of an Economics course.

Overall, the mixed results reported in the literature suggest that LC can have a positive effect on learning in the right set of circumstances.

1.2 Is LC an effective substitute for face-to-face lectures?
Again the literature’s answer to this is mixed. Several studies have shown that students that use lecture capture recordings...
In 2017, Powers and Carroll studied the effects of LC usage and how skipping class negatively affected their lower outcomes. Unfortunately, Bell et al. (2001) found that students were skipping class with the intention of not attending lectures. As might be expected, LC did lead to absenteeism in some (but definitely not all) studies (Bell et al. 2001, Powers and Carroll et al. 2008). Of course, it should also be mentioned that in other studies, LC recordings were actually found to be a good substitute for face to face lectures, with students performing equally well in both experimental groups (i.e. face-to-face and lecture capture) (Spickard et al. 2002, Solomon et al. 2004, Wieling and Hofman, 2010). In particular, LC was deemed an effective substitute for live lecture, for students with a high GPA (Inglis et al. 2011).

Given the mixed results, it is speculated that there are likely several factors that determine whether LC can and will be used as an effective substitute of face-to-face lectures by the students. It was noted that students are more likely to review lecture captures if the course is lecture-based instead of activity-based, if the quality of the lecture recording is good, if the students are motivated and have educational maturity, and if other course resources do not provide the same material (Cardall et al. 2008, Danielson et al. 2014).

1.3 Does lecture capture lead to absenteeism?

As might be expected, LC did lead to absenteeism in some (but definitely not all) studies (Bell et al. 2001, Powers and Carroll 2017, Rahmann et al. 2018). Unfortunately, Bell et al. (2001) found that students were skipping class with the intention of accessing the lecture captures at a later date, and then not actually finding the time to do that, possibly contributing to their lower outcomes.

In 2017, Powers and Carroll studied the effects of LC usage over the span of two years in a pharmacology course for 2nd-year medical students. They found that attendance for each class was low, 25-31% (in a class of ~200) students and only 12-14% of students exhibited a high attendance level (attending >80% classes). The researchers attributed this low attendance to the availability of posted lecture captures. Similarly to Bell’s study, they found that poor attendance correlated with lower exam results. Whereas students with high attendance had significantly higher exam scores within the course, as well as 22 weeks later in a comprehensive National Board of Medical Examiners (NBME) exam.

However, there are things that look very promising for maintaining attendance. In most studies, as examined in the meta-analysis performed by Danielson et al. (2014), attendance was not affected by the addition of lecture capture. Likewise, in 2018, Nordmann et al. found that there was no relationship between attendance and recording use. Moreover, in Nordmann’s study, GPA, attendance, and recording use were all positive and synergistic predictors of high exam marks. In search of reasons for why student attendance is maintained in many courses, Rahmann et al. (2018) surveyed his engineering students. Eighty percent of the engineering students stated that LC technology is not sufficient on its own, especially if there are drawings, demos, student discussion, Q&A, or other activities in lecture that are not captured through the recording. This indeed is the drawback for most LC platforms as the camera typically only records the computer screen and the microphone only picks up the instructor’s voice.

In Rahmann’s study, 40% of the engineering students had previously taken courses with LCT so it was felt that they had a good understanding of the technology and its pros and cons. That comfort level could be seen in the survey results, as this subset of students stated they were more likely to believe that LC could fulfill most of their study needs rather than attending lectures. However, it appears that despite this belief, these students did not stop attending class. Attendance was actually maintained throughout the term at ~93% which was similar to previous years prior to the addition of lecture-capture.

Thus as with Rahmann's engineering courses, if attendance and student-teacher interaction is perceived to be beneficial to the learner, instructors are advised to take steps that ensure attendance, perhaps by including activities, demos, group work, problem solving, assignments, and/or quizzes during class time. In addition, students were more likely to attend classes that were efficient and well-taught making it time well spent.

In sum, there were two common factors that might be used to predict whether a drop in attendance would occur with the adoption of LC. 1) Courses with attendance drops were exclusively lecture-based courses and 2) Upper-year or post-graduate students were more likely to routinely skip classes when LC was available. In explaining these results, it was thought that these more experienced students were likely more educationally mature with better meta-cognition (though still over-confident). In addition, these students were more likely to succeed in these courses despite possibly having lower marks than if they had attended as well (Powers and Carroll 2017).
1.4 Which students benefit the most from LC?

There are a few theories as to which students will likely benefit the most from lecture capture. In 2007, Phillips et al. believed that first-year students would be less likely to attend lecture or access recordings due to immature metacognitive abilities and learning strategies. At the same time, Demetriadis and Pombortsis (2007) speculated that first-year students would actually benefit the most from lecture capture as introductory courses tend to focus on knowledge acquisition instead of the higher order thinking skills, such as problem solving and applied knowledge, that are central to 3rd and 4th year courses. In their study of first year students, Demetriadis and Pombortsis (2007) found that students taught in the control group via live-lecture had the same outcomes as students taught via LC. Though in a conscious effort to make sure students adhered to using LC in that group, they used short 8.37 minute e-lectures and implemented pre-tests and post-tests (consisting of open-ended questions) as well as requiring post-viewing student teacher meetings. During the meetings students were asked six review questions and were expected to pose their own questions to the instructor.

In a meta-analysis of the literature, Danielson et al. (2014) found that students were most likely to view and benefit from LC in courses that were fast-paced, relied heavily on lecture, were perceived as being important and relevant to their future, and were comprised of novel information not available in other formats. Furthermore, students were more likely to view captured lectures if all of the instructor’s annotations were recorded (e.g. digital ink was used instead of laser pointer). Along the same lines, classes that involved group work or hands-on work were less likely to be classes that students would view via lecture capture as much of that work would be missed in the recording. Additionally students felt they were more likely to view captured lectures, if the instructor was skilled in explaining material, rather than just reading from their slides. It was also noted that lectures that were disorganized would be more likely to be viewed in order to help with clarification.

In sum, if it is desirable that lecture captures are used by students for review or in flipped or web-based learning classes, there are a few recommendations in producing them: a) make short videos on challenging content, b) make videos with embedded questions that must be answered, c) make videos that have testable content, that are novel and not found in other student resources, d) make sure videos are well organized and posted in an organized manner that is user-friendly, e) have post-tests or post-student-teacher meetings to discuss the videos (Demetriadis and Pombortsis 2007, Danielson et al. 2014).

When thinking about whether live-lecture or lecture capture is the most beneficial for students, it is also worth considering a study by Varao-Sousa and Kingstone (2015) who found that their students performed better in short-term memory tests if they attended live-lecture rather than watched lecture videos. In addition, they found that students found the material less interesting and were less motivated when the material was on video lecture rather than live lecture suggesting that having a live professor and possibly a particular setting involving other students, is important in student engagement and learning (Gysbers et al. 2011, Varao-Sousa and Kingstone 2015).

1.5 Do students believe LC is beneficial to their learning?

All studies found that access to some form of recorded lecture (webcast, videos, clips) increased student satisfaction (Inglis et al. 2011, Gosper et al. 2008, Davis et al. 2009, Folley 2010, Le et al. 2010). Students appreciated the flexibility of having LC available and having a choice in their learning approaches (Mattick et al. 2007). Students appreciated having the extra resources even if they didn’t use them. Furthermore, having ready access to a good “back-up” in case they did need help with clarification, review, or missed lecture was valued and even alleviated anxiety in some cases (Danielson et al. 2014, Kay 2012). When surveyed in these and the following studies, the four main reasons students cited for wanting access to LC is:

a. **Clarification**: Lecture recordings that have fast forward, double speed, and replay options can be skimmed through to review sections for clarification (Leadbeater et al. 2013).

b. **Learning**: Lecture recordings can be accessed and used at an individualized pace, and in a chosen environment (perhaps less distracting or alongside a tutor, sign language interpreter, or learning assistant) and in a time that better suits the student’s personal learning and scheduling. In this way LC assists with ownership of learning and making time spent more efficient and productive. Lecture recordings specifically with pause and replay features were found to be helpful to ESL (English as a Second Language) students and students with physical or learning disabilities (Simpson 2006, William 2006, Pearce and Scutter 2010, Nordmann et al. 2018).

c. **Revision**: Lecture recordings can be used for revision (Winer and Cooperstock 2002, Brotherton and Abowd 2004, Scutter et al. 2010).

d. **Catch-up**: Lecture recording can be used for making up missed sessions or to catch-up on things missed in class (Wilson and Weiser 2001, Taplin et al. 2014, Eisen et al. 2015). Interestingly, Rahman et al. (2018) found students can have difficulty maintaining attention during face-face lectures. In which case, students found that reviewing lecture recordings was helpful making it possible for them to fill in or clarify gaps in their notes. Moreover, lecture recordings were also cited as being helpful during periods of the day when student mind concentration level is low (afternoons and evenings) and also when the course was found to be difficult (Rahman et al. 2018). It was also noted that lecture recordings are helpful for students whose

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1.6 Do faculty believe LC is beneficial to their learning?
Danielson et al. (2014) found that faculty perception on the value of LC on learning was somewhat more muted in comparison with the students. Students were extremely positive, with 93% of students indicating that they were very or somewhat likely to learn better with lecture capture. In contrast, only 36.4% of faculty felt that LC would be somewhat or very likely to help students learn better, and 45.5% of faculty indicated that LC would be unlikely to affect learning. Faculty had 3 main concerns:

a. Drop in attendance affecting student learning and classroom dynamic: Some faculty worried that a drop in attendance may occur and affect the classroom dynamic and therefore the ability of the instructor.

b. Students doing less and achieving less: In addition, it was seen as a risk that students would skip class and then not make time for LC or not learn as well through LC.

c. Spending time creating resources that students do not use or need. Guy et al. (2017) found that the short eight to ten minute interactive video clips focusing on difficult content was accessed by only 50% of the cohort even though the student feedback was very positive. Students stated that the clips were engaging, assisted understanding of course content, and provided lecture support. Guy et al. (2017) found that the clip usage did correlate with higher exam marks though were not sure whether GPA or more self-regulation were the main factors in the deeper learning and higher outcomes.

d) Students believe it is helpful, but what if more of the same, is just more of the same, and not helpful? This potential problem is one that may be difficult to predict and discern for both faculty and students until the term is over. Nordmann et al. (2018) studied the effect of LC when offered across four years of an undergraduate degree programs. Firstly and perhaps not surprisingly, they found that the achievements of honours students did not seem affected by attendance or recording use. High-achieving, upper-year students are typically motivated and have acquired better metacognition and educational maturity. As expected, Nordmann et al. did however find that both attendance and recording use correlated positively with performance in first-year students and to a lesser degree in second-year students. In fact, in both first-year and second-year students, they found the greatest benefit of lecture recording use was by students with a low incoming GPA that had high attendance. Additionally they found that higher-achieving students were able to use recordings as a substitute for low attendance. Remarkably though, high recording usage and high attendance by students with a high incoming GPA, correlated with lower grades in the course, indicating that these students were struggling with the content and the recordings were not as helpful as one would have wanted them to be for these students.

As one might expect, there are a few theories that try to explain why some students benefit from certain educational resources and why some students do not. On the surface, it appears that students have different preferences in terms of which materials they wish to use in their learning (live lectures, textbooks, readings, demos, hands-on activities, group work, videos, etc.) (Kolb 1976, Marriott 2002). In addition, it is thought that some students prefer to learn while actively engaged, while others prefer to learn through the reflective processing (Kolb 1976, Marriott 2002). It has also been noted that each student’s learning style preferences may be different depending on the subject, and also may change over time as the student progresses in their learning, builds up experiences, and matures (Kolb 1976, Marriott 2002). In addition, students have a whole myriad of other factors in their lives which may play a role at any point in time (e.g. can they afford a textbook or access to the internet, do they have excessive demands on their time or attention with family or job, etc.). Of course there are limitations to the studies mentioned thus far as well as this one. In most cases students are not randomly assigned to only have access to specific resources. Secondly, if the measure of success is exam performance, is this an accurate reflection of their learning and is the learning deep or superficial, long-lasting or short-lived?

Purpose
Recording and posting lectures for students has many potential benefits. It may serve as a supplemental resource that may prove helpful for students who miss something during class or would like to review a challenging topic again on their own time. Most anatomy, physiology, and pathophysiology courses are fairly fast-paced delivering a lot of content. In addition, anatomy, physiology, and pathophysiology lectures are typically designed to help demonstrate or explain information found in course readings, possibly even providing more or additional information than what is found in course textbooks. So a resource that allows the lecture to be replayed could definitely prove valuable to students.

In addition, with early morning classes in a wintry climate, of course there are times that students are not fully awake or have difficulties arriving on time due to the weather. In these cases, LCT could provide a safety-net for students. With large classrooms, LCT can also provide benefits for students who would like to meet with the instructor for review sessions or office hours, but whose schedules at times does not permit it, due to work, course, family, or other obligations.

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The potential negatives of introducing such a resource is that students may stop attending class with the belief that reviewing lectures on their own time is possible and then not follow through with the review. As mentioned in the literature, a student may be tempted to put off viewing the recordings until too late in which case the number of videos becomes overwhelming. Another risk in skipping class with the intention of viewing the recorded lecture, is of course the potential for the LCT recording device to fail on that day preventing a recording from being captured and posted. LCT relies on classroom Wi-Fi to be working as well as the microphone and recorder and podium computer. The goal of this study was to assess the implementation of LCT into five different courses across three years of a four-year degree program, and determine whether the differing factors and layout of each course would support successful adoption.

Methods
Course Descriptions
This study was approved by the UBC Behavioral Research Ethics Board (Ethics Certification: H13-02-39) and informed consent was obtained from all participants. The study focused on assessing the implementation of LCT in five courses with content in the fields of human anatomy, physiology, and pathophysiology. The courses studied took place in the 2016-2017 academic year and are within two four-year university degree programs (Bachelor of Human Kinetics, BHK, and Bachelor of Science in Nursing, BSN). Four of the courses are within the Human Kinetics program. Those courses were: first-year Anatomy and Physiology Level I (180 students, HMKN190, fall semester), first-year Anatomy and Physiology Level II (174 students, HMKN191, winter semester), second-year Lifespan Motor and Physical Development (179 students, HMKN203, winter semester), and third-year Pathophysiology (152 students, HMKN335 fall semester). The fifth course, second-year Pathophysiology for nursing students (117 students, HINT231, fall semester) is in the Nursing program. The vast majority of students in all five courses are 18 to 21 years of age. All courses are lecture based and the two first-year anatomy and physiology courses also have weekly labs. Therefore, students enrolled in these courses attended a lecture section that met either 2x80min./week (HMKN190, HMKN191), 3x50min./week (HMKN203), or 1x160min./week (HINT231). The two Pathophysiology courses (HMKN335 and HINT231) differ in scope. HMKN335 covers major diseases and disorders of four organ systems: Musculoskeletal, Respiratory, Cardiovascular, and Neurologic Systems. HINT231 is a more intense course that covers major diseases and disorders of all organ systems.

Research Method:
It was desired the that LCT be implemented in these five heavy core courses to provide additional student study resources. At the same time, the goal was to assess the effectiveness and value of such a tool in classes that differ in depth on the Bloom’s taxonomy scale, as well as in levels of student maturity, metacognition, and workload. As such, LCT was implemented in each of the five courses (HMKN190, HMKN191, HMKN203, HMKN335, and HINT231), with lectures recorded using MediaSite and a portable microphone worn by the instructor to ensure both instructor’s screen and voice, and could accommodate movement and activity. Each of the courses is predominantly lecture–based but also include daily practice questions, electronic device (e.g. lap top or cell phone) Q&A time, demos, and hands-on activities. Demos and hands-on activities were not recorded as per the limitations of such software. The instructor did repeat student questions and answers so they were overlaid on to the visual recordings of the moment. These audio-visual lecture recordings were posted to the respective course websites immediately after each class. Attendance was not mandatory but was recorded in HMKN190 and HMKN191. In addition, all students in each course were surveyed at the end of term. After the fall semester, HMKN190 students move on to take HMKN191 in the winter semester, so were surveyed only at the end of HMKN191. The surveys assessed student perspective on LCT use and value as well as that of other class activities in order to gain perspective on how students viewed all of these resources (Figures 1-4). The surveys were as follows:

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FIRST-YEAR ANATOMY AND PHYSIOLOGY (HMKN190/191) STUDENT SURVEY:
1. I listened to some of the Recorded Lectures at least once.
2. I listened to most of the Recorded Lectures at least once.
3. I found the Recorded Lectures helpful for reviewing the material.
4. I found the Recorded Lectures helpful, because I could view it at my own pace.
5. I found the Recorded Lectures helpful, because I could view it at a time that was convenient to me.
6. I would rather have Recorded Lectures than in-class lectures.
7. Having the Recorded Lectures was valuable, because there is a lot of content in this course.
8. The Recorded Lectures were a useful part of this course.
9. The Recorded Lectures were easy to use.
10. The Recorded Lectures suits my way of learning.
11. I prefer learning through Recorded Lectures rather than reading the textbook.
12. I would rather come to class than learn through Recorded Lecture.
13. I felt more engaged in the class material because Recorded Lectures Technology was used.
14. Recorded Lectures should be used in this course in the future.
15. I think the practice questions given to us in the on-line quizzes on Connect were helpful.
16. I think the practice questions and other textbook resources were helpful in learning and studying the topics in this course.
17. I believe that the practice questions presented at the beginning of class were helpful.
18. I like to use an electronic device in class for course material.
19. I found the textbook helpful in learning studying the topics.
20. I kept up and reviewed the Lecture Material each week.
21. I found the Poster Scavenger Hunt Challenge increased the level of student interaction and discussion in our lab.
22. I think an hour of tutorial per week for this class would be helpful.
23. I would have attended an hour of tutorial per week for this class if it was run by an SL leader.
24. I would have attended an hour of tutorial per week for this class if it was run by the course instructor.

Figure 1. First-Year A&P Human Kinetics Student Survey. The students were given this optional 6-point Likert scale survey at the end of term which was completed by 94 consenting students.

FIRST-YEAR ANATOMY AND PHYSIOLOGY (HMKN190/191) STUDENT SURVEY:
1. I listened to some of the Recorded Lectures at least once.
2. I listened to most of the Recorded Lectures at least once.
3. I found the Recorded Lectures helpful for reviewing the material.
4. I found the Recorded Lectures helpful, because I could view it at my own pace.
5. I found the Recorded Lectures helpful, because I could view it at a time that was convenient to me.
6. I would rather have Recorded Lectures than in-class lectures.
7. Having the Recorded Lectures was valuable, because there is a lot of content in this course.
8. The Recorded Lectures were a useful part of this course.
9. The Recorded Lectures were easy to use.
10. The Recorded Lectures suits my way of learning.
11. I prefer learning through Recorded Lectures rather than reading the textbook.
12. I would rather come to class than learn through Recorded Lecture.
13. I felt more engaged in the class material because Recorded Lectures Technology was used.
14. Recorded Lectures should be used in this course in the future.
15. I think the practice questions given to us in the on-line quizzes on Connect were helpful.
16. I think the practice questions and other textbook resources were helpful in learning and studying the topics in this course.
17. I believe that the practice questions presented at the beginning of class were helpful.
18. I like to use an electronic device in class for course material.
19. I found the textbook helpful in learning studying the topics.
20. I kept up and reviewed the Lecture Material each week.
21. I found the Poster Scavenger Hunt Challenge increased the level of student interaction and discussion in our lab.
22. I think an hour of tutorial per week for this class would be helpful.
23. I would have attended an hour of tutorial per week for this class if it was run by an SL leader.
24. I would have attended an hour of tutorial per week for this class if it was run by the course instructor.

Figure 2. Second-Year A&P Human Kinetics Student Survey. The students were given this optional 6-point Likert scale survey at the end of term which was completed by 104 consenting students.
SECOND-YEAR NURSING PATHOPHYSIOLOGY (HINT231)
STUDENT SURVEY:
1. I listened to some of the Recorded Lectures at least once.
2. I listened to most of the Recorded Lectures at least once.
3. I found the Recorded Lectures helpful for reviewing the material.
4. I found the Recorded Lectures helpful, because I could view it at my own pace.
5. I found the Recorded Lectures helpful, because I could view it at a time that was convenient to me.
6. Having the lecture recording was valuable, because I found the three hour class too long.
7. I found the 3 hour class is too long.
8. I think this class would be better if it was twice a week (2x 80min) rather than once a week (1x180min).
9. The Recorded Lectures were a useful part of this course.
10. The Recorded Lectures were easy to use.
11. The Recorded Lectures suits my way of learning.
12. I prefer learning through Recorded Lectures than reading a textbook.
13. I attended all 3 hours of each class, this term.
14. I would rather come to class than learn through Recorded Lecture.
15. I felt more engaged in the class material because Recorded Lectures Technology was used.
16. I like using an electronic device in class for course material.
17. Recorded Lectures made me feel comfortable learning and reviewing new material.
18. Recorded Lectures should be used in this course in the future.
19. I found the “Think About” and “End of Slideshow” questions in this course helpful.
20. I found it was helpful when the instructor provided the Answers to the “Think About” and “End of Slideshow” questions.
21. The Endocrine Videos (e.g. Diabetes, Cushing’s, Thyroid Hormone) shown in class and posted to Connect were helpful.
22. The Digestive System Video apps shown in class were helpful. (Those ones are not able to be posted to Connect)
23. I kept up with Lecture Material each week.

Figure 3. Second-Year Nursing Student Survey. The students were given this optional 6-point Likert scale survey at the end of term which was completed by 67 consenting students.

THIRD-YEAR HUMAN KINETICS PATHOPHYSIOLOGY
(HMKN335) STUDENT SURVEY:
1. I listened to some of the Recorded Lectures at least once.
2. I listened to most of the Recorded Lectures at least once.
3. I found the Recorded Lectures helpful for reviewing the material.
4. I found the Recorded Lectures helpful, because I could view it at my own pace.
5. I found the Recorded Lectures helpful, because I could view it at a time that was convenient to me.
6. I would rather have Recorded Lectures rather than in-class lectures.
7. Having the lecture recording was valuable, because there is a lot of content in this course.
8. I listened to the Recorded Lectures each week.
9. The Recorded Lectures were a useful part of this course.
10. The Recorded Lectures were easy to use.
11. The Recorded Lectures suits my way of learning.
12. I prefer learning through Recorded Lectures than reading a textbook.
13. I would rather come to class than learn through Recorded Lecture.
14. I felt more engaged in the class material because Recorded Lectures Technology was used.
15. Recorded Lectures should be used in this course in the future.
16. I like using an electronic device in class for course material.

Figure 4. Third-Year A&P Human Kinetics Student Survey. The students were given this optional 6-point Likert scale survey at the end of term which was completed by 110 consenting students.

During data analysis, the following questions were addressed:

a. Do students use the LCT recordings? If so, how much?
b. Is there a difference between classes in how much the LCT recordings are used?
c. Do students find LCT valuable, easy to use, convenient, and/or helpful?
d. Do students appreciate LCT as much as other class activities: practice questions, in-class assignments, and use of electronic devices for Q&A?
e. Is there a correlation between perceived LCT value and appreciation of other class activities?
g. Is there a correlation between exam grades and perceived LCT value (or usage)? Is LCT of more value to low-scoring students?
h. Is there a correlation between attendance and perceived LCT value (or usage)?
i. Is there a correlation between attendance and course grades?
j. Is attendance affected by the use of LCT?
k. Does gender play a role in the perceived value of LCT?

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Results and Discussion
Evaluation of Student Use of LCT
The number of views of LCT was tracked anonymously through MediaSite software and can be viewed on the software’s dashboard. In addition, the time-points within the recording that are viewed are also tracked, as well as the length of time (number of minutes) that each recording is viewed. At the end of term, this anonymous data was collected for each class and plotted (Figures. 6-9). Firstly, as anticipated, it was found that most students did not view the entire recording for each lecture. Typical examples of viewing habits are documented in Figure 5. It is noted that students were selective and would view specific sections throughout the recording, unique to their own preferences.

Specifically, each viewing student accessed on average about 17-37% of the entire recording, indicating that they were focusing on sections that they felt they needed to review or clarify. First-year students viewed the fewest number of minutes on average per recording (at 17-18% or 11-12 min.) (Figure. 4). Their viewing habits increased between Term 1 and Term 2, possibly as they became more acclimatized to the university setting, or through friend-referral and/or assistance. It is also possible that students began to appreciate LCT as a study resource over time, or developed greater metacognitive skills that led to the inclusion of more study resources in their study plan. Attendance did drop slightly in Term 2 (by 10%), which is historically typical. The drop would only accounts for about half the increase in LCT viewing, if there was a specific relationship.

Third-year students viewed a few more minutes per recording, averaging 22-25% (15-17 min.) of each recording (Figure. 7). Second-year students viewed the greatest percentage of each recording, on average at 31% in HMKN203 and 29% in HINT231 (Figures. 5 and 6). In terms of number of views, the third-year students recorded the highest number of views per student (92% of the class); followed by HMKN191 (71% of the class); followed by HMKN203 (63% of the class) and lastly HINT231 (37% of the class). This is assuming that one view translates into one viewing student, though it is of course possible that one student accessed the same recording multiple times. This illustrates one limitation of the study, in that MediaSites’ tracking abilities are anonymous, which means that the number of views by each specific student is not recorded.
Figure 6. First-Year Anatomy and Physiology Human Kinetics Student LCT Viewing Data. a) Students in term 1 (HMKN190) recorded 85 views per recording on average and watched approximated 11 min. (17%) of each recording. If the 85 views translates to one view-per-student that implies 45% of the class utilized this LCT study tool each day. b) Students in term 2 (HMKN191) recorded 118 views per recording on average and watched approximated 12 min. (17%) of each recording. If the 118 views translates to one view-per-student that implies 71% of the class utilized the LCT study tool each day (a 26% increase from Term 1). It was also noted that LCT usage is fairly consistent throughout each term.

Figure 7. Second-Year Human Kinetics Student LCT Viewing Data. Students in HMKN203 recorded 112 views per recording on average and watched approximated 12 min. (31%) of each recording. If 112 views is one view-per-student that implies 63% of the class utilized the LCT study tool each day. It was noted that LCT usage increases as the term progresses, with a drop in the last two weeks. There are at least two possible reasons for this trend. The drop may be due to students getting busier with end of term of assignments and exams. It may also reflect the difficulty levels in course content as most students find the middle section of this course the most difficult.
Lecture Capture Technology (LCT): Following some rules and breaking others. The advantages, perks, and pitfalls of LCT implementation in large human anatomy, physiology, and pathophysiology classrooms.

It was found that with all the courses, there were two time-points in the term when LCT were accessed by the students most frequently: the first, being within a day or two of the actual class; and the second being in the days leading up to the final exam. This matched our predictions based on the literature.

It was also anticipated that LCT usage would increase as first-year Human Kinetics students progress through Term 1 and 2 and then into the second year (HMKN203). Based on the literature, we expected students to develop time management and study skills, educational maturity and metacognition, and become more pro-active in utilizing student study resources in a strategic manner.

It is worth noting that our predictions about viewing and usage were fairly accurate with the exception that the Nursing Pathophysiology students who used the LCT tool much less than expected, especially given their poor attendance and strong academic drive. We attribute this to the heavy Nursing course load (7 courses/term). Furthermore, in a similar class to second-year Nursing Pathophysiology, in terms of content and

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Figure 8. Second-Year Nursing Student LCT Viewing Data. Students in HINT231 recorded 43 views per recording on average and watched approximately 19min. (29%) of each recording. If 43 views is one view-per-student that implies 37% of the class utilized the LCT study tool each day. It was noted that LCT usage decreases quickly as the term progresses. There are at least two possible reasons for this trend. The drop may be due to students having an extremely loaded schedule, taking 7 courses per term and simply not having time to utilize the LCT resource. Another plausible explanation is that students in this class heavily favoured studying from the lecture PowerPoints which were made available and were crafted in such a way to be the “Cole’s notes” for the class. Again, it is likely this mode of studying was a time-saving mechanism for the students.

Figure 9. Third-Year Human Kinetics Student LCT Viewing Data. a) Students in Section 1 of HMKN335 recorded 80 views per recording on average and watched approximately 17min. (25%) of each recording. If 80 views is one view-per-student that means 90% of the class utilized the LCT study tool each day. b) Students in the Section 2 of HMKN335 recorded 59 views per recording on average and watched approximately 15min. (22%) of each recording. If 59 views is one view-per-student that indicates 94% of the class utilized the LCT study tool each day. It was noted that LCT usage is fairly consistent throughout each term.

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delivery, the third-year Pathophysiology students actually used the LCT tool much more than expected. At the same time, attendance in this third-year course was high and remained high for the entire term, despite thoughts that attendance would drop as a result of LCT implementation. The popularity of LCT in HMKN335 may be due to the heavy content of the course, in addition, to the perceived value of all of the Q&A that were in every class that was captured on LCT. This class requires a lot of memory as well as problem-solving skills that the students are just beginning to use. The practice Q&A illustrate step by step how to answer questions about various disease and drug mechanisms.

Student Satisfaction Survey Results

In order to determine whether students found LCT valuable, easy to use, convenient, and/or helpful, optional surveys were given to students at the end of term. Ninety-four first-year students consented and opted to take the survey. The results of the survey are documented in Table 1 and it is noted that overall, the students responded in a very favourable way to the implementation of LCT. The results of this table were condensed into Figure 10 to better visualize the trends found for each survey question.

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. I listened to some of the Recorded Lectures (RL) at least once.</td>
<td>46%</td>
<td>19%</td>
<td>11%</td>
<td>2%</td>
<td>10%</td>
<td>13%</td>
<td>0%</td>
</tr>
<tr>
<td>Q2. I listened to most of the Recorded Lectures at least once.</td>
<td>32%</td>
<td>6%</td>
<td>14%</td>
<td>7%</td>
<td>20%</td>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>Q3. I found the RL helpful for reviewing the material.</td>
<td>43%</td>
<td>16%</td>
<td>20%</td>
<td>6%</td>
<td>4%</td>
<td>9%</td>
<td>2%</td>
</tr>
<tr>
<td>Q4. I found RL helpful, because I could view it at my own pace.</td>
<td>45%</td>
<td>24%</td>
<td>16%</td>
<td>2%</td>
<td>3%</td>
<td>9%</td>
<td>1%</td>
</tr>
<tr>
<td>Q5. I found RL helpful, because I could view at a time that was convenient to me.</td>
<td>49%</td>
<td>21%</td>
<td>15%</td>
<td>1%</td>
<td>4%</td>
<td>7%</td>
<td>2%</td>
</tr>
<tr>
<td>Q6. I would rather have RL than in-class lectures.</td>
<td>7%</td>
<td>5%</td>
<td>12%</td>
<td>27%</td>
<td>23%</td>
<td>23%</td>
<td>2%</td>
</tr>
<tr>
<td>Q7. Having the RL was valuable, because there is a lot of content in this course.</td>
<td>52%</td>
<td>24%</td>
<td>16%</td>
<td>1%</td>
<td>0%</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Q8. The RLs were a useful part of this course.</td>
<td>40%</td>
<td>27%</td>
<td>17%</td>
<td>4%</td>
<td>3%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>Q9. The RLs were easy to use.</td>
<td>43%</td>
<td>34%</td>
<td>12%</td>
<td>3%</td>
<td>1%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Q10. The RLs suits my way of learning.</td>
<td>32%</td>
<td>18%</td>
<td>22%</td>
<td>7%</td>
<td>11%</td>
<td>9%</td>
<td>1%</td>
</tr>
<tr>
<td>Q11. I prefer learning through RLs rather than reading the textbook.</td>
<td>29%</td>
<td>16%</td>
<td>20%</td>
<td>9%</td>
<td>14%</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>Q12. I would rather come to class than learn through RL.</td>
<td>24%</td>
<td>27%</td>
<td>23%</td>
<td>14%</td>
<td>5%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Q13. I felt more engaged in the class material because RL Technology was used.</td>
<td>10%</td>
<td>19%</td>
<td>26%</td>
<td>28%</td>
<td>9%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>Q14. RLs should be used in this course in the future.</td>
<td>47%</td>
<td>27%</td>
<td>18%</td>
<td>3%</td>
<td>1%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Q15. I think the practice questions given to us in the on-line quizzes were helpful.</td>
<td>45%</td>
<td>35%</td>
<td>15%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>Q16. I think the textbook resources were helpful in learning &amp; studying course topics.</td>
<td>27%</td>
<td>23%</td>
<td>18%</td>
<td>2%</td>
<td>1%</td>
<td>1%</td>
<td>28%</td>
</tr>
<tr>
<td>Q17. I believe the practice questions presented at the beginning of class were helpful.</td>
<td>39%</td>
<td>32%</td>
<td>18%</td>
<td>5%</td>
<td>2%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Q18. I would like to use an electronic device in class for course material.</td>
<td>24%</td>
<td>44%</td>
<td>20%</td>
<td>5%</td>
<td>4%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>Q19. I found the textbook helpful in learning studying the topics.</td>
<td>15%</td>
<td>23%</td>
<td>30%</td>
<td>14%</td>
<td>9%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Q20. I kept up and reviewed the Lecture Material each week.</td>
<td>5%</td>
<td>13%</td>
<td>44%</td>
<td>16%</td>
<td>16%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Q21. I found the Poster Challenge increased student interaction &amp; discussion in our lab.</td>
<td>17%</td>
<td>17%</td>
<td>27%</td>
<td>21%</td>
<td>10%</td>
<td>6%</td>
<td>2%</td>
</tr>
<tr>
<td>Q22. I think an hour of tutorial per week for this class would be helpful.</td>
<td>28%</td>
<td>26%</td>
<td>30%</td>
<td>5%</td>
<td>5%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Q23. I would have attended 1hr of tutorial/wk if it was run by an SL leader.</td>
<td>19%</td>
<td>18%</td>
<td>26%</td>
<td>20%</td>
<td>11%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Q24. I would have attended 1hr of tutorial/wk if it was run by the course instructor.</td>
<td>44%</td>
<td>29%</td>
<td>16%</td>
<td>5%</td>
<td>1%</td>
<td>3%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 1. Anonymous survey responses of 94 first-year students at the end of term. The condensed survey results for responses in the category of Agree (Strongly Agree, Agree and Somewhat Agree) and for responses in the category of Disagree (Strongly Disagree, Disagree, and Somewhat Disagree) are shown in Figure 10.
After looking at the Mediasite viewing data (as laid out in Figure 6 for HMKN190/191), it appears that students were accurate and truthful when answering the first two questions of the survey regarding the number and amount of recorded lectures that they actually viewed. As anticipated, in answer to questions 3-5, and 7-10, the vast majority of students (72-88%) found that LCT was helpful for review and useful because it could be viewed at their own pace, at a convenient time, was easy to use, and suited their way of learning. Question 6 was similar to question 12, and most first-year students (74%) would rather come to class than view the recorded lectures. This was higher than we expected, as the class is very large (174 students), located in a dark lecture hall, early in the morning (8am), and wintery driving conditions prevail for much of the term. Even though attendance is not mandatory, it is thought that the daily practice questions as well as additional material taken on during class time encourages attendance. Perhaps most importantly, 91% of first-year students felt that LCT should be used in the future. Furthermore, LCT held up equally favourably to other class resources which were surveyed in questions Q19-21 and garnered between 61-95% in positive responses (Table 1). The responses to the final questions (Q22-24) were somewhat anticipated as the course is very content heavy. The students currently have two optional one-hour guided study sessions per week with a trained third-year student (SL leader). Currently, these sessions typically attract low numbers of high-achieving students. At the end of term, likely more students feel they should have participated.

For second-year Human Kinetics students, as can be seen in Table 2 and Figure 11, the survey results were very similar to those of the first-year students and even more favourable in response to some questions concerning LCT. The vast majority (81-92%) of students found that LCT was helpful for review, useful because it could be viewed at their own pace, at a convenient time, was easy to use, and suited their way of learning. For questions 1 and 2 regarding self-reporting of LCT usage, the numbers are higher than one might expect from MediaSite’s tracking data (Figure 7). It is likely that students were over-estimating their use of LCT. Question 6 was similar to question 12, and most students would rather come to class than view the recorded lectures. This was higher than we expected, as attendance is not taken. It is thought that the time (11am-12noon) is conducive to attendance, as well as the extra material that is covered in class in comparison to the textbook is a drawing factor. Interestingly, just as with the first-year students, 91% of second-year students felt that LCT should be used in the future, even though likely some had not used it at all. Moreover, LCT held up equally favourably to other class resources which were also surveyed in questions 17-22 and had received in the range of 82-94% in positive responses (Table 2). The responses to the final two questions (Q21 and 22) were somewhat anticipated as students like using their electronic devices for practice Q&A and the lectures add more material than the textbook covers. Additionally many students do not buy a textbook.
### 2nd yr HK Student LCT Survey (n=140)

**Table 2.** Results of 2nd year HK LCT Student Satisfaction Survey (n=140). The condensed survey results for responses in the category of Agree (Strongly Agree, Agree and Somewhat Agree) and for responses in the category of Disagree (Strongly Disagree, Disagree, and Somewhat Disagree) are shown in Figure 11.

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. I listened to some of the Recorded Lectures (RL) at least once.</td>
<td>51%</td>
<td>26%</td>
<td>8%</td>
<td>1%</td>
<td>8%</td>
<td>6%</td>
<td>0%</td>
</tr>
<tr>
<td>Q2. I listened to most of the RLs at least once.</td>
<td>35%</td>
<td>14%</td>
<td>22%</td>
<td>4%</td>
<td>16%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Q3. I found the RLs helpful for reviewing the material.</td>
<td>45%</td>
<td>28%</td>
<td>14%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Q4. I found the RLs helpful, because I could view it at my own pace.</td>
<td>50%</td>
<td>26%</td>
<td>14%</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Q5. I found the RLs helpful, because I could view it at a time that was convenient to me.</td>
<td>54%</td>
<td>28%</td>
<td>10%</td>
<td>1%</td>
<td>2%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>Q6. I would rather have RLs than in-class lectures.</td>
<td>8%</td>
<td>11%</td>
<td>12%</td>
<td>30%</td>
<td>23%</td>
<td>16%</td>
<td>1%</td>
</tr>
<tr>
<td>Q7. Having the RLs was valuable, because there is a lot of content in this course.</td>
<td>54%</td>
<td>31%</td>
<td>7%</td>
<td>3%</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Q8. The RLs were a useful part of this course.</td>
<td>44%</td>
<td>36%</td>
<td>11%</td>
<td>3%</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Q9. The RLs were easy to use.</td>
<td>43%</td>
<td>38%</td>
<td>11%</td>
<td>4%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Q10. The RLs suits my way of learning.</td>
<td>32%</td>
<td>29%</td>
<td>20%</td>
<td>8%</td>
<td>4%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>Q11. I prefer learning through RLs rather than reading the textbook.</td>
<td>38%</td>
<td>25%</td>
<td>19%</td>
<td>10%</td>
<td>5%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>Q12. I would rather come to class than learn through RLs.</td>
<td>21%</td>
<td>30%</td>
<td>31%</td>
<td>9%</td>
<td>5%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Q13. I felt more engaged in the class material because RL Technology was used.</td>
<td>23%</td>
<td>21%</td>
<td>25%</td>
<td>20%</td>
<td>4%</td>
<td>4%</td>
<td>3%</td>
</tr>
<tr>
<td>Q14. RLs should be used in this course in the future.</td>
<td>54%</td>
<td>25%</td>
<td>14%</td>
<td>1%</td>
<td>1%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Q15. I think the practices questions given to us in the on-line quizzes were helpful.</td>
<td>45%</td>
<td>34%</td>
<td>15%</td>
<td>1%</td>
<td>4%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Q16. I kept up and reviewed the Lecture Material each week.</td>
<td>9%</td>
<td>16%</td>
<td>33%</td>
<td>24%</td>
<td>12%</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Q17. The Baby Brain Video Assignment was useful in understanding neurogenesis.</td>
<td>21%</td>
<td>38%</td>
<td>26%</td>
<td>5%</td>
<td>6%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Q18. The Mercury Poisoning Assignment was useful in understanding toxins.</td>
<td>18%</td>
<td>34%</td>
<td>30%</td>
<td>11%</td>
<td>4%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Q19. The Stem Cell Assign. was useful in understanding stem cells, GFs, &amp; hormones.</td>
<td>19%</td>
<td>34%</td>
<td>29%</td>
<td>9%</td>
<td>6%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Q20. The Diabetes Assign. was useful in understanding the roles of insulin, T1D, &amp; T2D.</td>
<td>21%</td>
<td>43%</td>
<td>24%</td>
<td>7%</td>
<td>3%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Q21. I would like to use an electronic device in class for course material and Q&amp;A.</td>
<td>24%</td>
<td>26%</td>
<td>25%</td>
<td>13%</td>
<td>6%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Q22. I found the textbook helpful in learning studying the topics.</td>
<td>9%</td>
<td>6%</td>
<td>26%</td>
<td>21%</td>
<td>21%</td>
<td>12%</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Figure 11.** Condensed Results of 2nd year HK LCT Student Satisfaction Survey (n=140).
The third-year Human Kinetics Pathophysiology class responded in a similar manner within their survey as with those of the first-year cohort for all the questions regarding LCT use and value (Table 3, Figure 12). Also similarly, the majority of students were still keen to come to class, with only 21% stating that they would rather have recorded lectures than face-to-face class. It is hypothesized that again the in-class activities, that cannot be recorded (Q&A, video clips), and possibly student-instructor engagement would be the main reasons for students wanting to come to class. In addition, the classes were held in the early afternoon, which is a convenient time for the vast majority of our students. Furthermore, by second and third year, the Human Kinetics students have formed fairly strong bonds with their peers (despite the large class sizes) and appear to thrive in the high-energy that brings to the classroom. Attendance is not mandatory in this class, but from the instructor’s perspective, the introduction of LCT did not affect attendance. Attendance remained similar to that of previous years.

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. I listened to some of the Recorded Lectures (RL) at least once.</td>
<td>45%</td>
<td>24%</td>
<td>8%</td>
<td>2%</td>
<td>20%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Q2. I listened to most of the RLs at least once.</td>
<td>35%</td>
<td>9%</td>
<td>15%</td>
<td>2%</td>
<td>20%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Q3. I found the RLs helpful for reviewing the material.</td>
<td>46%</td>
<td>19%</td>
<td>14%</td>
<td>4%</td>
<td>3%</td>
<td>11%</td>
<td>5%</td>
</tr>
<tr>
<td>Q4. I found the RLs helpful, because I could view it at my own pace.</td>
<td>54%</td>
<td>23%</td>
<td>10%</td>
<td>3%</td>
<td>1%</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>Q5. I found the RLs helpful, because I could view it at a time that was convenient to me.</td>
<td>54%</td>
<td>23%</td>
<td>9%</td>
<td>2%</td>
<td>3%</td>
<td>6%</td>
<td>5%</td>
</tr>
<tr>
<td>Q6. I would rather have Recorded Lectures rather than in-class lectures.</td>
<td>4%</td>
<td>6%</td>
<td>11%</td>
<td>17%</td>
<td>29%</td>
<td>32%</td>
<td>2%</td>
</tr>
<tr>
<td>Q7. Having the RLs was valuable, because there is a lot of content in this course.</td>
<td>54%</td>
<td>26%</td>
<td>10%</td>
<td>3%</td>
<td>1%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Q8. I listened to the Recorded Lectures each week.</td>
<td>14%</td>
<td>8%</td>
<td>11%</td>
<td>15%</td>
<td>23%</td>
<td>28%</td>
<td>3%</td>
</tr>
<tr>
<td>Q9. The Recorded Lectures were a useful part of this course.</td>
<td>42%</td>
<td>24%</td>
<td>17%</td>
<td>6%</td>
<td>2%</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td>Q10. The Recorded Lectures were easy to use.</td>
<td>54%</td>
<td>25%</td>
<td>10%</td>
<td>1%</td>
<td>1%</td>
<td>6%</td>
<td>4%</td>
</tr>
<tr>
<td>Q11. The Recorded Lectures suits my way of learning.</td>
<td>34%</td>
<td>23%</td>
<td>22%</td>
<td>5%</td>
<td>5%</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>Q12. I prefer learning through Recorded Lectures than reading a textbook.</td>
<td>42%</td>
<td>18%</td>
<td>14%</td>
<td>9%</td>
<td>5%</td>
<td>11%</td>
<td>3%</td>
</tr>
<tr>
<td>Q13. I would rather come to class than learn through Recorded Lecture.</td>
<td>25%</td>
<td>26%</td>
<td>18%</td>
<td>10%</td>
<td>11%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td>Q14. I felt more engaged in the class material because RL Technology was used.</td>
<td>32%</td>
<td>32%</td>
<td>19%</td>
<td>11%</td>
<td>3%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>Q15. Recorded Lectures should be used in this course in the future.</td>
<td>18%</td>
<td>17%</td>
<td>26%</td>
<td>19%</td>
<td>8%</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>Q16. I like using an electronic device in class for course material.</td>
<td>25%</td>
<td>29%</td>
<td>20%</td>
<td>12%</td>
<td>6%</td>
<td>7%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 3. Results of third-year HK LCT Student Satisfaction Survey (n=110). The condensed survey results for responses in the category of Agree (Strongly Agree, Agree and Somewhat Agree) and for responses in the category of Disagree (Strongly Disagree, Disagree, and Somewhat Disagree) are shown in Figure 12.

Figure 12. Condensed Results of 3rd year HK LCT Student Satisfaction Survey (n=110)
Surprisingly, the second-year Nursing Pathophysiology class responded in a very similar manner in their survey compared to the first-, second-, and third-year Human Kinetics students (Table 4, Figure 13) despite the fact that their attendance and LCT viewing habits were strikingly lower in comparison with the Human Kinetics courses (Figure 8). The Nursing Pathophysiology course was held on Mondays from 3-6pm on a day with back to back lectures. This schedule is in place in the Nursing program to leave Tuesdays-Fridays free for their clinical course work in the downtown hospital. These students are heavily loaded with seven courses per term. As reported by both students and the instructor, it was found that by Monday at 3pm, the students were exhausted and had a hard time concentrating in class. The majority of students stopped coming to class, even though it meant missing activities and video clips in-class. These in-class activities are low-stakes activities, as they are in the Human Kinetics classes previously discussed. The majority of Nursing students chose to learn through posted PowerPoints of the lectures material instead. Interestingly, despite the low attendance and low LCT viewings, 82-94% of respondents stated that they found the lecture recordings helpful for reviewing, valuable due to the length of the Monday classes, and helpful for viewing at one’s own pace at a time that was convenient. In the open answer comment box within the survey, many students did state, that although they had not personally used the LCT, they knew classmates who were using it and benefitting greatly from them. Again, LCT was viewed favourably as was the in-class and posted student resources as cited in answers to questions 16-23. It is hypothesized that although most of the Nursing students did not use LCT, they appreciated having a “back-up” just in case the lecture PowerPoint notes needed clarifying.

<table>
<thead>
<tr>
<th>Q1. I listened to some of the Recorded Lectures (RL) at least once.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>39%</td>
<td>33%</td>
<td>6%</td>
<td>3%</td>
<td>7%</td>
<td>12%</td>
<td>0%</td>
</tr>
<tr>
<td>Q2. I listened to most of the RLs at least once.</td>
<td>16%</td>
<td>24%</td>
<td>21%</td>
<td>6%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>Q3. I found the RLs helpful for reviewing the material.</td>
<td>28%</td>
<td>42%</td>
<td>12%</td>
<td>7%</td>
<td>1%</td>
<td>7%</td>
</tr>
<tr>
<td>Q4. I found the RLs helpful, because I could view it at my own pace.</td>
<td>36%</td>
<td>40%</td>
<td>15%</td>
<td>0%</td>
<td>0%</td>
<td>6%</td>
</tr>
<tr>
<td>Q5. I found the RLs helpful, because I could view it at a time that was convenient to me.</td>
<td>46%</td>
<td>31%</td>
<td>16%</td>
<td>0%</td>
<td>0%</td>
<td>4%</td>
</tr>
<tr>
<td>Q6. Having the RL was valuable, because I found the three hour class too long.</td>
<td>36%</td>
<td>34%</td>
<td>13%</td>
<td>6%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Q7. I found the 3 hour class is too long.</td>
<td>54%</td>
<td>27%</td>
<td>7%</td>
<td>3%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Q8. I think this class would be better if it was (2x 80min) rather than (1x180min).</td>
<td>67%</td>
<td>24%</td>
<td>3%</td>
<td>0%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Q9. The Recorded Lectures were a useful part of this course.</td>
<td>42%</td>
<td>36%</td>
<td>13%</td>
<td>1%</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>Q10. The Recorded Lectures were easy to use.</td>
<td>40%</td>
<td>34%</td>
<td>12%</td>
<td>6%</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>Q11. The Recorded Lectures suits my way of learning.</td>
<td>28%</td>
<td>30%</td>
<td>18%</td>
<td>4%</td>
<td>6%</td>
<td>9%</td>
</tr>
<tr>
<td>Q12. I prefer learning through Recorded Lectures than reading a textbook.</td>
<td>24%</td>
<td>25%</td>
<td>18%</td>
<td>13%</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>Q13. I attended all 3 hours of each class, this term.</td>
<td>7%</td>
<td>10%</td>
<td>12%</td>
<td>9%</td>
<td>31%</td>
<td>30%</td>
</tr>
<tr>
<td>Q14. I would rather come to class than learn through Recorded Lecture.</td>
<td>16%</td>
<td>30%</td>
<td>28%</td>
<td>13%</td>
<td>9%</td>
<td>1%</td>
</tr>
<tr>
<td>Q15. I felt more engaged in the class material because RL Technology was used.</td>
<td>6%</td>
<td>25%</td>
<td>33%</td>
<td>21%</td>
<td>7%</td>
<td>7%</td>
</tr>
<tr>
<td>Q16. I like using an electronic device in class for course material.</td>
<td>24%</td>
<td>42%</td>
<td>21%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Q17. RLs made me feel comfortable learning and reviewing new material.</td>
<td>24%</td>
<td>34%</td>
<td>19%</td>
<td>12%</td>
<td>3%</td>
<td>7%</td>
</tr>
<tr>
<td>Q18. Recorded Lectures should be used in this course in the future.</td>
<td>43%</td>
<td>33%</td>
<td>18%</td>
<td>3%</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>Q19. I found the practice questions in this course helpful</td>
<td>43%</td>
<td>33%</td>
<td>19%</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Q20. I found it was helpful when provided with answers to the practice questions.</td>
<td>67%</td>
<td>27%</td>
<td>4%</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Q21. The endocrine videos shown in class and posted to Connect were helpful.</td>
<td>31%</td>
<td>42%</td>
<td>24%</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Q22. The digestive system videos shown in class and posted to Connect were helpful.</td>
<td>24%</td>
<td>36%</td>
<td>34%</td>
<td>1%</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>Q23. I kept up with Lecture Material each week.</td>
<td>18%</td>
<td>28%</td>
<td>18%</td>
<td>12%</td>
<td>4%</td>
<td>9%</td>
</tr>
</tbody>
</table>

Table 4. Results of 2nd year Nursing LCT Student Satisfaction Survey (n=67). The condensed survey results for responses in the category of Agree (Strongly Agree, Agree and Somewhat Agree) and for responses in the category of Disagree (Strongly Disagree, Disagree, and Somewhat Disagree) are shown in Figure 13.

continued on next page
Finally, as one might expect, with each of the four classes and four surveys, Pearson correlational analysis revealed that there were strong correlations between the positive responses on related questions. Strong correlations and clusters of positive responses exist in the HMKN191 survey (Q1-14 and Q21). In addition, three clusters exist in the HMKN203 survey: i) Q1-11, 13-14; ii) Q12 and 15; and iii) Q17-20. Furthermore, three clusters exist in the HINT231 survey: i) Q1-6, 9-12, 15, 17, and 18; ii) Q7 and 8; and iii) Q13-14. Lastly, three clusters exist in the HMKN335 survey responses: i) Q1-12, 15-18; ii) Q13-14, and iii) Q19-21. This is not surprising as the questions were related to each other, so students would be more likely to answer them in the same ways.

**Student Survey Responses in Relation to Exam Marks and Final Grades**

We were interested to know whether high-achieving or low-achieving students benefited most from LCT. Pearson correlational analysis revealed weak correlations between low exam scores and positive responses to survey questions regarding LCT as well as other student resources. However this was only found to be the case in the first-year course, specifically with the following questions: Q1-3, Q6-11, and Q13. These results indicate that LCT in first-year was the most popular with low-scoring students, either because they used it the most, and/or because they perceived LCT as having a lot of value.

**The Effects of LCT on Attendance**

Daily attendance was only actively monitored in the first-year courses, though the instructor of all of these courses did not feel that attendance changed at all from previous years with the implementation of LCT. This is with the exception of the nursing course (HINT231), in which case it was the first time this course was offered so no previous data exists. Attendance data and number of recorded views per day for first-year Anatomy and Physiology is shown in Figure 14. Attendance was consistent with historical numbers and did not drop as a result of the implementation of LCT.
As might be expected, Pearson correlational analysis revealed weak correlations between low attendance and positive survey responses to the LCT questions in the first-year course. This means that students who had lower attendance valued LCT to a greater degree. A further analysis was done with the first-year data to determine whether there is a relationship between attendance and course grades. Weak Pearson correlations exist between high attendance and midterm results (0.217, significant at the 0.05 level, 2-tailed) and moderately strong Pearson Correlations were found between high attendance and final grades (0.474, significant at the 0.01 level, 2-tailed).

Gender difference in LCT survey and grades and attendance. In all of these courses, female students outnumber male students. It was noted in the literature that female students were more likely than male students to view videos (Wiese and Newton 2013). In order to determine whether a similar phenomenon occurred in the first-year course and whether there were gender differences in attendance and grades, attendance and exam data were collected and compared in an anonymous manner by students that consented to the study. It was found that male students (n=38) were less likely to come to class than female students (n=101). For example, in HMKN190, the average attendance rate for males was 69.25%. Males on average attended 69.25% of the total number of classes in the term. Females on average attended 82.15% of the total number of classes in the term. This 13% difference widened to 16% in the second term in HMKN191.

Interestingly, according to Q1 and Q2 responses in the survey, first-year males were less likely to view LCT, and on average answered disagree or somewhat disagree to those viewing questions. On the other hand, females on average, were more likely to answer positively to those two questions. In terms of the survey, this was the end of the gender differences, as the rest of the survey was answered similarly between male and females. Surprisingly, there were significant differences found between many of the exam grades, as shown in Table 5. Though it is speculated that the strong correlation between attendance and grades likely accounts for this phenomenon.
The other courses (HMKN203, HMKN335, and HINT231) were analyzed in a similar manner, to determine whether gender differences existed in self-reported LCT viewing, attendance, survey responses, and grades. No differences were found.

**Conclusions**

Overall, the implementation of LCT in five different courses met our hypothesis that students would respond favourably and appreciate the additional study tool. LCT will be something that is continued to be used in the future. The students found the LCT helpful for clarifying their notes after class, for reviewing prior to exams, and for catching up on days that they were absent from class. It saved some students time in that they could access the instructor’s help via LCT at times that was convenient to them, and at a pace that suited them. Recordings could be sped up or slowed down and it was evident that students picked and chose which areas of the recording to view (averaging at approximately 25% length of the total recording). In this way, students could take charge of their own learning and possibly develop educational maturity and metacognitive skills. Some students mentioned juggling work or other courses in the survey comment section and it meant they did not have to worry about arranging to attend office hours or tutorials. It helped the varsity athletes who had to be away for games and tournaments. It also helped students with disabilities as well as the tutors, TAs, and scribes for the course.

For all of the courses, the number of views was higher than expected, with the exception of the Pathophysiology for Nursing course, which had fewer views than expected. The nursing class logged the lowest number of views per day (~37% of the class) and the third-year Human Kinetics students logged the highest number of views per day (~94% of the class). As the nursing course did have the most content, it was anticipated that the usage of LCT in this class would be the highest. In addition, the low attendance in this course, also led one to believe that LCT would be used a lot, however this was not the case, likely due to the heavy course load in this program that placed high demands on time. Despite this, nursing students responded similarly in the student satisfaction survey as students in the other courses, responding very favourably to the implementation of LCT and valuing it just as much as other course resources (practice questions, video clips, demos, and in-class activities).

In addition, we were interested to note that in the first-year anatomy and physiology course in which attendance was monitored, there were: i) weak Pearson correlations observed between lower grades and positive perceived value of LCT as per survey responses; and ii) a moderate to strong correlation between attendance and course grades. Finally, we were surprised to note that in this first-year course (and only in this course) there were significant differences between the genders in: i) a self-reported use of LCT; ii) attendance; and iii) exam and final grades for the course.

**Literature Cited:**


Lecture Capture Technology (LCT): Following some rules and breaking others. The advantages, perks, and pitfalls of LCT implementation in large human anatomy, physiology, and pathophysiology classrooms.
The Case for Alzheimer’s Disease as Type 3 Diabetes

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Abstract
A growing body of evidence supports the concept that Alzheimer’s Disease (AD) is a metabolic disease that results from impaired insulin signaling, insulin resistance, and low levels of insulin in the brain. Because the molecular and biochemical consequences of impaired insulin signaling are shared with Type 1 and Type 2 diabetes, the term “Type 3 diabetes” has been suggested for AD. There is also evidence that people who have Type 2 diabetes have a heightened risk of developing AD. Understanding the possible associations between Type 2 diabetes and AD may lead to effective early diagnosis and treatment of AD. It may also help to identify patients with Type 2 diabetes who are at high risk for developing AD. In this article, we examine the possible associations between Type 2 diabetes and AD. doi: 10.21692/haps.2018.002

Key words: Alzheimer’s disease, diabetes, insulin resistance, amyloidogenesis, neuroinflammation

The information contained in this article will enhance student comprehension of the neuroendocrine system and their appreciation for the current research associated with a possible link between Alzheimer’s Disease and Diabetes, associated with the pedagogy of courses in Human Anatomy and Physiology, Human Physiology, Advanced Physiology and Neurobiology.

Introduction
The first indication that patients with Type 2 diabetes mellitus (T2DM) have an increased risk of developing Alzheimer’s Disease (AD) appeared in the Rotterdam study (Dar et al. 2014), a prospective study that has been ongoing since 1990 in Rotterdam, The Netherlands (Ikram et al. 2017). Participants in the Rotterdam study, who currently number 14,926 individuals over the age of 40, are monitored for a variety of diseases that are known to affect the elderly, among them: heart disease, stroke, AD, Parkinson’s disease, diabetes, and osteoporosis. The Honolulu-Asia Aging Study, initiated in 1990 to study abnormalities associated with dementia in 3734 Japanese-American men and closed in 2012 (Gelber et al. 2012), similarly found a strong association between T2DM and AD (Peila et al. 2002). The number of people who suffer from these diseases is staggering. Conservative estimates put the number of people with AD at 36 million worldwide and that number is expected to double every twenty years until 2040 (Narasimhan 2014). The number of people who suffer from diabetes may exceed 347 million worldwide (Yang and Song 2013). Diabetes mellitus is associated with the subsequent development of AD in the aging population (Dar et al. 2014) and people with T2DM are believed to be 50-65% more likely to develop AD as they age compared to people who are not diabetic (Dar et al. 2014, http://dlife.com/type-3-diabetes, www.diabetes.co.uk/type3-diabetes.html). There is currently a debate about the degree to which T2DM and perhaps T1DM contribute to the pathogenesis of AD that centers on the rising prevalence of obesity, T2DM and AD over the past 20 years. Some degree of association between diabetes and AD is suggested by the following (de la Monte and Wands 2008):

1. An increased risk for developing mild cognitive impairment (MCI), dementia, or AD in patients who have been diagnosed with T2DM.
2. The presence of progressive insulin resistance (IR) and insulin deficiency that has been observed in the brain of Alzheimer’s patients.
3. Observations of cognitive impairment in animal models of T2DM and obesity.
4. Neurodegeneration and cognitive impairment in animal models where IR or insulin deficiency have been induced.
5. Observations of improved cognitive performance in experimental animals who have received intranasal insulin treatment for cognitive impairment.
6. The presence of several biochemical and molecular abnormalities that are shared in T2DM and AD. (de la Monte and Wands 2008)
Type 3 diabetes is a name that has been proposed for AD in reference to the insulin resistance that is characteristic of the disease and the growing recognition that it may be a form of neuroendocrine disorder (Narasimhan 2014). Initial studies that were carried out at the Brown University Warren Alpert Medical School established that IR can occur in the brain and later studies undertaken by lead researcher, Dr. Suzanne de la Monte in 2012, confirmed that IR is a critical part of the progression of AD (de la Monte 2017, www.diabetes.co.uk/type3-diabetes.htm).

In this article, we examine the possible associations between T2DM and AD.

**Clinical manifestations of AD and T2DM**

Clinically AD is characterized by progressive behavioral changes, short-term memory loss, a decline in executive functions, and a decrease in cognition (de la Monte 2017). Neurodegeneration typically begins before the disease has been acknowledged and treatment sought. Neurodegeneration includes atrophy of the cortical white matter, neuro-inflammation, microvascular disease, accumulation of hyper-phosphorylated tau (pTau) and an increase in amyloid beta deposits in plaques, blood vessels, and neurons (de la Monte 2017). The structural lesions that are associated with dementia are caused by the collapse of the cytoskeleton in neurons (de la Monte and Wands 2008). The cerebral atrophy that characterizes AD is the result of the progressive loss of fibers and cells and the targeting of glutamatergic synapses (de la Monte and Wands 2008).

T2DM is characterized by insulin resistance (IR), hyperinsulinemia, and glucose tolerance. The hyperglycemia that results from these conditions leads to oxidative stress and non-enzymatic glycation of important regulatory proteins, which affects the ability of these proteins to function properly (Kamal et al. 2014).

Alzheimer’s Disease and T2DM are both chronic progressive diseases characterized by inflammation (Kamal et al. 2014). AD is so widespread it has been described as the pandemic of the 21st century and T2DM is one of the most common metabolic diseases in the world. The incidence of the occurrence of both diseases increases with age. The possibility that T2DM increases the chance of getting AD and the ways in which the two diseases may be linked is an area of extensive current research (Kamal et al. 2014). There is a growing belief that this research may point to a neuroendocrine basis for AD and the eventual renaming of the disease as Type 3 diabetes (Dar et al. 2014).

**Type 1 and Type 2 Diabetes**

Diabetes is a chronic debilitating disease that occurs when the pancreas becomes incapable of producing adequate amounts of the hormone insulin and/or when the body cannot effectively take up and utilize the insulin that is produced. The classic sign of both T1DM and T2DM is hyperglycemia.

Type 1 diabetes strikes quickly and unpredictably. The body mistakenly perceives the insulin-producing pancreatic beta cells as foreign, which results in a swift and complete autoimmune-mediated destruction of the beta cells (Davidson 1981). Insulin production ceases and blood glucose levels quickly rise to life threatening levels. While the exact cause of T1DM remains unknown, current research suggests that there is a genetic predisposition for the condition combined with an environmental trigger, such as a virus (Davidson 1981). While T1DM can affect persons of any age, it is most commonly associated with children or young adults (IDF 2015).

Type 2 diabetes represents 90-95% of diagnosed cases of diabetes (IDF 2015) and while it has previously been associated primarily with older patients, the current epidemic of T2DM is also sweeping up sedentary, overweight young people.

Type 2 diabetes is characterized by a relative deficiency of insulin and it has a slower onset than T1DM, often going unnoticed for many years prior to diagnosis. A diagnosis of T2DM is often preceded by a pre-diabetes phase that may or may not be detected in time for a possible reversal of the disease. T2DM patients have a dual defect: a slow decline in pancreatic beta-cell function along with IR. Pre-diabetes and T2DM are more predictable than T1DM and both are potentially reversible if diagnosed early (Davidson 1981).

Obesity is the strongest predictor of T2DM across all populations and the risk of T2DM is magnified two-fold in those individuals who are exposed to food insecurity (ADA 2018).

**Possible Mechanisms of Association Between Alzheimer’s Disease and Diabetes**

The primary associations between AD and T2DM are insulin resistance, inflammation, and amyloid load. These conditions are discussed below along with several other possible associations between the two diseases. Importantly, the amyloid load of Alzheimer’s disease exacerbates insulin resistance in the brain, while insulin resistance increases the amyloid load. These factors create a positive feedback that may underlie the progression of symptoms in both diseases and their relationship with one another.

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**Insulin Resistance**

Insulin Resistance (IR) is described as the reduced ability of cells and tissues to physiologically respond to insulin levels (Dar et al. 2014). It is seen in many disorders including diabetes, metabolic syndrome, AD, and generalized cognitive impairment. Recent research suggests that impaired insulin signaling might be linked to many of the abnormalities associated with AD, including neuro-inflammation (de la Monte 2017).

Amyloid accumulation in the brain exacerbates the hallmark insulin resistance of T2DM in a number of ways, including effects on insulin receptor density and effectiveness within neurons. Abnormal levels of insulin receptors have been observed in brains of patients with AD, especially in the hippocampus and hypothalamus (Frolich et al. 1998, Steen et al. 2015). Amyloid beta (Aβ) oligomers, hallmarks of the AD brain, can also cause internalization of insulin receptors, decreasing the responsiveness of neurons to insulin (Zhao et al. 2008, de Felice et al. 2009). Not only can Aβ decrease the density of insulin receptors on the neurons, but these oligomers can also change the sensitivity of the molecular pathways through which the insulin receptors act in neurons. Aβ signals interrupt the molecular signals within the neurons that are used by activated insulin receptors, adding another layer to the interference of Aβ with insulin signals within the neurons. Specifically, Aβ42 decreases activation by phosphorylation of Akt in human neuronal cell cultures (Lee et al. 2009) and decreased pAKT is observed in brains of patients with Alzheimer’s (Steen et al. 2005, Liu et al. 2011).

The brain is extremely sensitive to insulin and insulin receptors are widely distributed in brain tissue. Any disruption in insulin signaling can affect the plasticity of synapses and the viability of neurons (Kamal et al. 2014, Yang and Song 2013). The biochemical and molecular consequences of insulin resistance in the brain are similar to the consequences of insulin resistance in other organs. Specifically, however, the disruption of insulin signaling in the brain may result in the death of neurons, a decrease in energy available to brain cells, altered expression of the genes for insulin production, changes in neural plasticity and changes in the integrity of the white matter of the cortex (Dar et al. 2014, de la Monte 2014).

In the brain, insulin accelerates the uptake and transport of glucose. The resulting erratic glucose levels may lead to the development of the plaques and neurofibrillary tangles that are characteristic of AD (Dar et al. 2014). Since glucose is the primary fuel molecule for the brain, any interruption in glucose uptake by brain cells can cause the cells to starve. Starvation at the cellular level increases the rate of cell death, produces oxidative stress, and impairs homeostasis (Dar et al. 2014).

Resistance to insulin typically progresses slowly but when IR becomes more pronounced, the pancreas is unable to counteract the decrease in insulin levels in body tissues and it begins to increase the amount of insulin it produces. This leads to hyperinsulinemia, which in turn leads to T2DM (Dar et al. 2014). Insulin deficiency, insulin resistance, and hyperinsulinemia are involved in the cognitive impairments that are sometimes observed in diabetes patients (Dar et al. 2014).

An area of intense current investigation concerns the possibility that the changes in insulin signaling may be such that with peripheral impairment the result is T2DM, and with centralized impairment the result is AD (Dar et al. 2014).

**Mitochondrial dysfunction**

Neurons rely heavily on ATP production in mitochondria for the energy to produce, and to maintain and restore the sodium/potassium pump. In diabetes, mitochondrial dysfunction includes changes in the morphology of mitochondria, calcium build-up in cells, and a decrease in the capacity of biosynthetic and antioxidant reactions (Yang and Song 2013). In Alzheimer’s patients, a disruption in the energy production capabilities of mitochondria occurs prior to plaque formation (Yang and Song 2013).

**Neuro-inflammation**

Neuro-inflammation, which is associated with many neurodegenerative diseases, refers to the presence of microglia and astrocytes that cause the release of pro-inflammatory cytokines and other inflammatory products such as reactive oxygen species and lipid peroxidation products (de la Monte 2017). In the brain, neuro-inflammation injures neurons and causes cholinergic dysfunction. This leads to oxidative stress, which damages nerve terminals and disrupts synaptic function. Disruption of synaptic function results in cognitive impairment. Neuro-inflammation is seen in several disorders of the central nervous system (CNS) including AD, infection, injury, multiple sclerosis, and stroke (de la Monte 2017).

Generalized inflammation is a condition shared by both diseases. Inflammation plays a role in IR in T2DM where it is primarily localized in the pancreatic islet cells. It is characterized by an increase in the numbers of islet macrophages and an increase in cytokines and chemokines (Yang and Song 2013). Inflammation is also present in AD, marked by an increase in the expression of the genes that are involved in inflammation, an increase in the activation of microglial cells, and an increase in the concentration of cytokines and chemokines. Specifically, Aβ oligomers that are elevated in AD decrease the sensitivity of insulin receptors, which increases insulin resistance within the brain (Bonfim et al. 2012, de Felice et al. 2013). Inflammation is always present in animal models of AD (Yang and Song 2013).

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Amyloid Accumulation
Amyloidogenesis is the generation of amyloid plaques and abnormally folded proteins, including Aβ, in the brain or other tissues. It is a shared pathological characteristic of T2DM and AD (Yang and Song 2013).

Historically, the hallmarks of AD have been the accumulation of amyloid plaques and tangled tau proteins (de la Monte 2014). In T2DM, analogous amyloid plates are deposited in the islets of the pancreas where they are a distinguishing feature in 90% of people with diabetes (Yang and Song and Song 2013). The amyloid plaques of diabetes are known as amylin or human islet amyloid polypeptide (hIAPP). Fibrils of hIAPP have a molecular structure and morphology that closely resembles the amyloid plaques seen in AD. Plaques of hIAPP induce beta cell apoptosis in the pancreas (Yang and Song 2013). Related functions of hIAPP remain unknown.

Amyloid accumulation occurs due to an increase in the rate of amyloid production, a decrease in the rate of amyloid clearance, or a combination of these problems. Many factors can increase amyloidogenesis by increasing the rate of Aβ formation, and several of these factors are associated with or increased in the T2DM brain. Neuroinflammation and oxidative stress are specifically associated with increased rates of amyloid production in the brain. Insulin and amyloid shared clearance mechanisms within the brain, meaning abnormally high levels of either molecule can impact clearance of the other (Qiu and Folstein 2006).

Oxidative stress
Oxidative stress, which occurs when the number of free radicals that are produced in cells exceeds the antioxidant capacity of the cell, is present in T2DM and AD. In situations of oxidative stress, biological molecules are damaged and cells die. The hyperglycemia that occurs in T2DM leads to the production of free radicals and oxidative stress. In AD, oxidative stress is known to occur prior to the development of amyloid plaques (Yang and Song 2013).

Advanced Glycation End Products
Normal aging leads to the accumulation of advanced glycation end products (AGEs). The rate of build-up of AGEs is accelerated in T2DM and in AD. In AD, the increased rate is due to accelerated oxidation of glycated proteins related to the presence of intracellular phosphates and sugars such as glucose and fructose. High levels of AGEs are also seen in the central nervous system of people with diabetes. The relative amount of AGEs present in the cerebrospinal fluid may one day act as a potential biomarker for the early detection of AD (Dar et al. 2014).

Dyslipidemia
Increased levels of free fatty acids, cholesterol, triglycerides, and LDL, coupled with reduced levels of HDL, are risk factors for both AD and T2DM (Dar et al. 2014).

Animal studies support the concept of AD as Type 3 diabetes
Perhaps some of the strongest evidence for an association between AD and T2DM comes from animal studies in which intracerebroventricular injections of the pre-diabetic (anti-insulin) drug streptozotocin were administered to rats (de la Monte 2014). The rats that were treated with streptozotocin developed cognitive impairments in spatial learning and memory in addition to IR in the brain, insulin deficiency, and neurodegeneration similar to that which has been observed in AD patients. The resulting clinical picture for the treated rats closely resembled that observed in humans with AD (de la Monte 2014).

Insulin Therapy in the Treatment of AD
The similarities in the pathology of AD and T2DM lead some researchers to believe that the drugs used to treat diabetes might be useful in the treatment of AD. Insulin has been used in the treatment of diabetes for decades.

Intranasal delivery of insulin
The brain needs insulin to support many metabolic functions including growth, the maintenance of myelin, and the survival of neurons. Unfortunately, insulin levels characteristically fall in AD. Consequently, insulin supplementation has been proposed as an experimental treatment for early AD. Insulin can be administered in a number of ways, primarily by subcutaneous, oral, or intranasal delivery. There has been concern about using injectable insulin to treat insulin deficiency in the brain because of the possibility of triggering systemic effects such as hypoglycemia and the uncertainty that the insulin will cross the blood brain barrier. Intranasal delivery of insulin is a non-invasive approach in which the treatment can go directly to the brain via olfactory and trigeminal nerves (de al Monte 2017).

Several studies have demonstrated that the treatment of AD patients with intranasal insulin improves brain energy metabolism and general cognition in the mild cognitive impairment that characterizes the early stage of AD. Insulin also encourages the clearance of amyloid plaques, decreases the activity of the kinases that are responsible for the production of tau tangles, and enhances the signals that promote synaptic plasticity (de la Monte 2017). One of the big advantages to intranasal deliver of insulin is that it makes it possible to avoid multiple daily injections of insulin.

In spite of its record of treatment effectiveness, there are some concerns about the use of intranasal insulin in AD.
**Difficulties associated with intranasal delivery of insulin**

The delivery protocols for the use of intranasal insulin are not currently standardized. The delivery system needs to be standardized and it needs to be made easy enough for elderly patients or their caretakers to manage. Until this is done there is a danger of suboptimal dosing and unpredictable outcomes of the therapy (de la Monte 2017).

Inadvertent systemic delivery of insulin must be avoided. Systemic delivery of insulin can result in hypoglycemia, which can cause further damage to delicate areas of the brain.

The insulin used for intranasal therapy must be structurally stable, able to penetrate the nasal mucosa, and resistant to degradation (de la Monte 2017). The development of ultra-long-acting insulin with predictably sustained release and bioactive profiles is needed.

**Cognitive Impairment in T2DM and Obesity**

Type 2 diabetes mellitus is associated with several conditions that may have a negative impact on the brain, among them: hypertension, obesity, dyslipidemia, abnormalities of the hypothalamic-pituitary-adrenocortical (HPA) axis, and inflammation (Bruchl et al. 2009).

Cognitive impairment and structural abnormalities in the brain have been reported in people with T2DM. People with T2DM are most likely to have difficulty with verbal declarative memory and exhibit reduced volume in the prefrontal and hippocampal areas of the brain. HPA axis feedback control may be poor (Bruchl et al. 2009). Structural changes in the brain can affect both white and gray matter.

Central area obesity, as measured by the waist-hip ratio, is associated with reduced hippocampal volume and an increase in pathologies of the white matter of the cortex (Bruchl et al. 2009). It is important to note that studies in cognitive impairment as related to obesity have yielded inconsistent results over time. Dyslipidemia is associated with decreased cognitive performance (Bruchl et al. 2009).

A substantial number of cases of dementia are related to vascular risk factors which are associated with T2DM, dyslipidemia, hypertension and obesity. T2DM and hypertension are strongly associated with end-stage organ damage of the retina and kidney (van den Berg et al. 2009).

Type 2 diabetes patients are not routinely screened for cognitive outcomes and cognitive impairment in patients with T2DM is rarely referred for treatment. Similarly, AD patients are not currently screened for T2DM or hyperinsulinemia (Haan 2006). If a T2DM-AD link is definitively established, the clinical implications would include cognitive evaluation for patients diagnosed with T2DM and the referral of these patients for appropriate cognitive therapy (Haan 2006).

**Life Style Interventions**

A healthy diet coupled with adequate exercise is neuroprotective as well as being protective against diabetes and cardiovascular disease (de la Monte 2017). This diet appears to be particularly beneficial in the preclinical and very early stages of AD. Lack of physical exercise is associated with an increased risk of developing AD and sustaining mild cognitive impairment. An increase in physical activity is associated with an increase in the plasticity of neurons (de la Monte 2017). Mild exercise is associated with increased glucose regulation.

Diets rich in processed sugars contribute to the development of T2DM. Smoking is considered to be an avoidable risk for developing AD.

**Conclusion**

Aging remains the primary factor in the development of AD but evidence is accumulating that insulin and insulin-like growth factor resistance and disrupted insulin signaling in the brain may contribute to dementia, cognitive impairment and AD (de la Monte 2014). There may be an argument to be made that AD is really a neuroendocrine-based disease that is essentially a case of diabetes mellitus of the brain or Type 3 diabetes. The possible association that is being most closely investigated is the progressive IR observed in the brain of AD patients, even in the absence of T2DM, obesity, or the occurrence of IR in other areas of the body.

Postmortem studies have demonstrated that the molecular, biochemical, and signal transduction abnormalities observed in AD are identical to those that are found in Type 1 and Type 2 diabetes mellitus (de la Monte 2014).

The evidence linking AD to diabetes and the risk factors for diabetes, such as adiposity and hyperinsulinemia, is strong but it falls short of considering any of these conditions to be the definitive causes of AD (Luchsinger 2008). The public health implications are huge if these conditions, particularly diabetes, are found to be causative agents for AD. Two-thirds of the adult population in the US is classified as either overweight or obese and this trend is being observed worldwide. When the true cause of AD is finally known, a large percentage of AD may prove to be treatable or preventable (Luchsinger 2008).

Studies focusing on lifestyle intervention and drug therapy have shown that hyperinsulinemia and the risk of diabetes can be managed. Perhaps the same may be true of AD. Finding the links between diabetes and the risk factors for diabetes and AD would allow clinicians to identify specific targets for treatment. More research into the possible associations between T2DM and AD is needed.
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Abstract
The purpose of this study was to develop a teaching guide to demonstrate the gross characteristics of pathology in embalmed cadaveric lungs and to assess the guide as an effective teaching tool. Ninety-eight embalmed cadaveric lungs were screened for pathology. The characteristics of pathologic states of the embalmed lungs were recorded and histopathologic confirmation was performed. Pneumonia, neoplasms, emphysema, chronic bronchitis and diffuse interstitial lung disease were the most commonly observed pathologic lesions. Discoloration of the parenchyma and edema were the most commonly observed artifacts from the embalming process. Medical and nursing students who used the guide had significantly more ability to identify pathologic lesions than control groups. This guide will assist faculty and students in obtaining the skills needed to examine and interpret the gross presentation of an embalmed cadaveric lung. doi: 10.21692/haps.2018.003

Key words: lung pathology, cadaver, gross anatomy, pathology, anatomy education

Introduction
There are many examples in the literature that highlight the educational importance of identifying pathology within a gross anatomy setting (Eisenstein et al. 2015, Wood et al. 2015, Geldenhuys et al. 2016, Rae et al. 2016). Although most of these reports cite specific examples of pathologic instances and how they can be utilized as integrative learning opportunities, none of them address the dependence that anatomy faculty must have on clinical collaborators on reaching this goal. Without the clinical knowledge of pathology, or the knowledge about how the embalming process changes the body, many questions remain unanswered about the normal and abnormal presentation of cadaveric lungs. For example, does the lung retain extra fluid after the embalming process? There is much information pertaining to the post-mortem changes that occur in lungs (Shiotani et al. 2004). However, little information is available that describes the uniqueness of the embalmed cadaveric lung. It has been shown that the embalming process causes artifacts (Rae et al. 2015) and it is possible that embalming affects the gross presentation of all of the cadaveric organs. The lung is a dynamic organ that contributes to the respiratory and cardiovascular functions of the body. One end of the organ is open to the exterior environment and is subject to attack from microbial invasion and foreign bodies. The other integrating root of the lung is to the heart, where blood is progressively dwindled down into delicate pulmonary capillaries that make up the substance of most of the lung parenchyma.

When considering the pathologic lesions that are commonly found in the lower respiratory tract, inflammatory conditions from chemical and physical irritants and bacterial invasions are offending triggers, resulting in bronchitis, bronchiectasis, pneumonia, emphysema, pulmonary fibrosis and pneumoconiosis. Due to the integration of the lung with the cardiovascular system, the lung is frequently a site of metastasis by tumor cells that are traveling in the vascular system as well as a site for pulmonary congestion resulting from left-sided heart failure.

The delicate anatomic structure of the lung renders the organ susceptible to the normal pathologic processes such as tumors, inflammation and infections that occasionally occur in the body’s internal environment, but also renders it susceptible to repeated insults of inhaled impurities, irritants and microbes.

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There are several textbooks and atlases that describe the gross and histopathologic presentation of diseased lungs (Cooke and Stewart 2004, Riede and Werner 2004, Kumar et al. 2014). However, resources that describe the presentation of an embalmed normal lung are scarce. This is most likely because autopsy patients are not usually embalmed prior to clinical evaluation.

Willed bodies are used in academic medical and health professional schools in dissection courses in human anatomy (Biasutto et al. 2014). It is been shown that individuals most often donate their bodies to science to advance the field of medicine (Bolt 2010). If pathologic lesions could be studied while the body is being dissected, the impact of the willed body would be greater than if the pathologic lesions are overlooked or not recognized (Rae 2016). An effective resource that describes the normal and abnormal presentation of embalmed lung tissue would assist faculty and students in identifying the pathologic lesions that are present and might serve to foster integrative learning opportunities.

The purpose of this study is to investigate the anatomic characteristics of the embalmed cadaver lung that are normal and identify pathologic lesions that are detectable under gross examination. After the anatomic investigation, the information was used to create an pathology guide that was designed to help students identify pathologic lesions in the gross anatomy laboratory and to assess the effectiveness of the pathology guide as an educational tool.

Methods
The Institutional Review Board (IRB) of Louisiana State University Health Sciences Center deemed the protocol exempt from IRB oversight (IRB# 8406). Ninety-eight cadaveric lungs were obtained from the gross anatomy laboratory after completion of the dissection process.

Gross evaluation of the organs
The lungs were weighed and the weight of each lung was recorded in grams. The pleurae were checked for abnormalities and lesions. The external surface of the lung was examined for any pleural adhesions, hard or opaque pleural regions. The lung was palpatated from the external surface for any noticeable hard lesions from within the parenchyma. If lesions were palpable, then tissue sections were taken for histopathologic evaluation.

Using a cell-path lung knife, the lung was cut in a frontal plane to allow for visual inspection of the lobes. Then, the parenchyma was palpated to examine for lesions. If there were palpable lesions that were not visibly seen in the section, additional slices were cut to examine more of the parenchyma. The bronchi and blood vessels were visually inspected to detect any obstructive elements. One tissue sample was taken from the periphery of the lung (including the pleural surface) and one sample was taken of tissue from the central portion of the lung for all specimens. Additional tissue samples were taken for regions of lesions.

Histologic examination of organs
The tissue cassettes, disposable plastic containers used to hold and identify tissue samples, were processed and embedded with paraffin wax using a standard overnight protocol using an Excelsior ES tissue processor. After placing the tissue in paraffin blocks using a Shandon Histocentre 3, the tissue was sectioned at five micrometers using a Leica RM 2135 microtome and manually stained with Hematoxylin and Eosin. Two board certified pathologists, each with over 10 years of experience, along with a senior pathology resident, examined the slides. The clinicians were blinded as to the gross observations that were described with each case.

Methods of qualitative analyses
All of the gross observations were placed in categories using a qualitative content analysis approach that included an open coding process followed by a selective coding process. Content analysis is method of qualitative research where words are coded, grouped and recoded to identify themes that exist within documents. For this process, an anatomist (PhD trained) with experience in qualitative research methodology read the written notes that were compiled after the gross and histologic evaluations. The documents were then coded in a two-phase process as described below.

The open coding process
Each individual raw observation was taken from the notes made at the time of gross examination of the heart. The observations were listed in their original language. Then, they were grouped together based on common themes and attributes. For example, individual categories such as “black lines” and “black spots” were grouped together into one category, “black lines and spots”. There were three rounds of grouping until the categories could not be condensed without losing their individuality. For example, “black lines and spots” would not be grouped together with “white lines and spots” because this would not allow an analysis between white and black discoloration of the parenchyma.

Selective coding process
After the grouping of observations, the list of categories was considered to be the proposed selective code. Then, using the selective coding system, the notes of the gross observations for each organ were re-read and the observations were placed in one of the categories from the selective code system. Saturation was achieved when all observations fit into a category and no additional categories were needed for completion of the analysis. The same coding process was used for the microscopic observations made by the pathologist.

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The most common selective codes for the gross and microscopic evaluations are presented in Tables 1 and 2.

**Table 1. Most prevalent lung gross observations**

<table>
<thead>
<tr>
<th>Observation</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracotic pigment (marbeling, lines, splotches)</td>
<td>80.41%</td>
</tr>
<tr>
<td>Levidity or dark reddish brown parenchyma</td>
<td>80.41%</td>
</tr>
<tr>
<td>Hard lesions in parenchyma (small/Lg. nodules)</td>
<td>33.00%</td>
</tr>
<tr>
<td>Pleural discoloration or hardening</td>
<td>28.87%</td>
</tr>
<tr>
<td>Collapsed/wrinkled surface of lung</td>
<td>26.80%</td>
</tr>
<tr>
<td>Granular/ Cobblestone-like outer appearance</td>
<td>22.68%</td>
</tr>
<tr>
<td>Discoloration of parenchyma (grey or black)</td>
<td>20.62%</td>
</tr>
<tr>
<td>Emphysema or holes/pockets in parenchyma</td>
<td>20.62%</td>
</tr>
<tr>
<td>Discoloration of parenchyma (white or light beige)</td>
<td>18.56%</td>
</tr>
<tr>
<td>White material in bronchi</td>
<td>10.30%</td>
</tr>
</tbody>
</table>

**Table 2. Most prevalent lung microscopic observations**

<table>
<thead>
<tr>
<th>Observation</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emphysema</td>
<td>53%</td>
</tr>
<tr>
<td>Chronic obstructive lung disease</td>
<td>41%</td>
</tr>
<tr>
<td>Chronic bronchitis</td>
<td>29%</td>
</tr>
<tr>
<td>Plexogenic arteriopathy</td>
<td>27%</td>
</tr>
<tr>
<td>Aspiration with foamy macrophages</td>
<td>20%</td>
</tr>
<tr>
<td>Acute bronchopneumonia</td>
<td>22%</td>
</tr>
<tr>
<td>Pleural scar</td>
<td>12%</td>
</tr>
<tr>
<td>Hemosiderin laden macrophages</td>
<td>12%</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>10%</td>
</tr>
<tr>
<td>Aspiration pneumonia</td>
<td>10%</td>
</tr>
<tr>
<td>Squamous metaplasia</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Statistical analysis**

A Phi correlation (φ) analysis was conducted among all categories in the selective coding systems (both gross and histologic) to determine statistical significance of correlations between the categories. This statistical analysis was conducted using the Graphpad Prism 6 software program. All correlations with a p value less than 0.05 were considered significant.

**Evaluation of pulmonary weight for evidence of artifact**

The normal mass for a male lung is 583g±216, mean± standard deviation, (left) and 663g±239 (right). The normal mass for a female lung is 467g±174 (left) and 546g±207 (right) (Grandmaison et al. 2001). Figure 1 shows the cases that had lungs above the normal range. Eight of the cadavers with “heavy” lungs had bilateral heavy lungs. Sixteen cadavers had unilateral “heavy” lungs. There are many reasons why a lung will weigh outside of the normal range such as infection, edema, hemorrhage and the presence of tumors. Any additional fluid or cells will increase the weight of the organ above the normal range. It is unknown whether the fixative solution used in the embalming process alters the weight of the cadaver’s lung; however, there has been an account of formalin fixation altering lung volume in rats (Dugiud et al. 1964). Out of all of the specimens, 36.08% of them were above the normal range for weight. Out of these cases, 50% did not have a gross or histologic cause for this change in weight. Fifty percent of the cases of “heavy lungs” had pathology that was consistent with the observed increase in weight. Therefore, it is likely that the embalming process causes a subsequent increase in the cadaver’s lung weight.

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After statistically analyzing all of the correlations between the gross and microscopic observations, a list of significant correlations was generated. The list was then analyzed based on basic pathologic principles to determine whether any of the correlations were indirect, or artificially created by the categorization process. Those items were removed from the results. The remaining correlations were considered of importance for creating the pathology guide (Table 3).

<table>
<thead>
<tr>
<th>Gross observation</th>
<th>Histologic observation</th>
<th>phi coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapsed/wrinkled lung</td>
<td>Pleural scar</td>
<td>$\phi = .337$</td>
</tr>
<tr>
<td>Firm but not hard palpable lesions</td>
<td>Pneumonia all types</td>
<td>$\phi = .535$</td>
</tr>
<tr>
<td>Hard lesions in parenchyma</td>
<td>Neoplasm (all types)</td>
<td>$\phi = .501$</td>
</tr>
<tr>
<td>White material in bronchi</td>
<td>Chronic bronchitis</td>
<td>$\phi = .325$</td>
</tr>
</tbody>
</table>

This table lists the significant correlations between the gross and histologic observations. The phi coefficient is used to detect an association between two variables. All of the significant correlations were positive, meaning that if one variable was present there was an association of another variable being present. Values represent a weak (0.3-0.5), moderate (0.5-0.7) and strong positive correlation (0.7-1.0).

The correlation between gross and microscopic observations suggested that those two observations occurred together but did not necessarily suggest any causative relationship between them. The clinically or diagnostically important correlations can do two things: assist an examiner in identifying likely microscopic observations that would be present if the gross characteristic is observed and support the current theories in the field of pathology that those gross and microscopic findings are related to each other.

The correlations that were determined as having diagnostic or clinical importance are seen in Table 3. The justification for their inclusion into the pathology guide is discussed below.

White material in the bronchi was positively correlated with the presence of chronic bronchitis. Chronic bronchitis is a form of chronic obstructive lung disease with anatomic alterations that are specific to the bronchi: increased bronchial glands (Restrepo and Heard 1963), hyperplasia of bronchial muscle (Hossain and Heard 1969), and metaplasia of the bronchial epithelium (Sanderud 1958; Christensen et al. 1977). In addition to these alterations in the bronchi, chronic bronchitis also involves small airway modifications that are seen in other diseases such as asthma and, therefore, cannot always be differentiated from asthma (Hargreave and Parameswaran 2006). The white matter found in the cadaver's bronchi most likely consists of mucus, because mucus is secreted in increased amounts by both goblet cells and submucosal glands in this condition.

The collapse of a lung and wrinkling of the visceral pleural surface was positively correlated with pleural scarring. The collapse of a lung is called atelectasis and fibrotic scarring of the pleura can cause retraction of the lung tissue (Williams 1969, English and Leslie 2006). Grossly, this retraction can be seen as a wrinkling of the surface or collapsed lung (Figure 2).
Palpable firm but not hard areas were positively correlated with the presence of pneumonia. This gross characteristic found in the cadaver’s lungs is also found in fresh lungs examined at autopsy (Cooke and Stewart 2004, Kumar et al. 2014). The palpable areas are respiratory regions filled with neutrophils, pus and bacteria (Figures 3 and 4).

**Figure 3**

*Figures 3 and 4. Presentation of bronchopneumonia.*

The photo above shows the gross presentation of bronchopneumonia and the photo below shows neutrophils and pus in the airways (20x).

Hard lesions in the parenchyma were positively correlated with neoplasms both metastatic and primary. Regardless of the body region, neoplasms are commonly found as dense, palpable masses (Kumar et al. 2014). The increased cellular growth associated with neoplasms renders them denser than the normal organ parenchyma. The increased density of the neoplasm makes it “palpable”, meaning that the inspector can feel them as hard areas within the organ. Therefore, even if the area looks similar in color, or is obscured from view, one can palpate the organ and feel for the presence of tumors.

Overall, from the data obtained during the gross and microscopic observations, there were several considerations that needed to be included in the pathology guide that are specific to the lung. In many instances, it seems more clinically necessary to palpate the lung for the presence of lesions than it is to visually inspect it, when compared to other organs that can be primarily visually inspected. For example, pleural plaques and calcifications, neoplasms and pneumonia all depend on the examiner’s ability to palpate the organ and differentiate normal and abnormal tissue in a tactile way. Therefore, this method of examining the lung was included as an important and necessary step in the inspection process.

Although photographs were used to assist the reader in visually targeting certain areas for examination, such as areas of pleural thickenings, the photographs are more important for detecting non-palpable pathologies such as chronic bronchitis and emphysema. From the survey of grossly observable characteristics, most lungs had levidity and anthracotic pigment. Although these observations are not directly the result of any pathologic process, they were included in the guide to give the students an explanation of their appearance. A cobblestone surface appearance was present in many of the lungs (Figure 5). The cobblestone surface was not statistically tied into any histologic observation. However, this gross presentation is tied to a general pathologic process of scarring and increased collagen deposition, which is supported by literature and was included in the guide (Kumar et al. 2014). Emphysema and chronic bronchitis were prevalent in the cadaver population. Therefore, the guide includes background information on these conditions along with the instructions for identifying them.
Figure 5. Cobblestone appearance of the surface of the lung. The rough surface of the lung is commonly referred to “cobblestone appearance”.

Evaluation of the Guide's Effectiveness

Content validation of the guide was performed by pathologists (n=3) and students (n=6; three second semester nursing students and three second year medical students). The guides were reviewed for the following categories: clarity in wording, relevance of items, use of standard English, absence of biased words or phrases, formatting of items, clarity of instructions (Fowler 2002). The content validation forms were qualitatively analyzed to identify themes in the reviewers' comments. The major suggestions were to add definitions of selected terms to the beginning or end of the guide and to elaborate on the instructions for palpating the lung specimens.

Assessment of the cadaver pathology guide's effectiveness

At Louisiana State University Health Sciences Center, both medical and nursing students take gross anatomy laboratory that involves cadaver dissection. In addition, both student populations also take a course in pathology in their second year of study.

After the students completed dissection during their gross anatomy course, but before they were enrolled in pathology, students were recruited to participate in a short educational intervention to measure the effectiveness of the pathology guides as a teaching resource.

Medical (n=87) and nursing (n=84) students were asked to use the guides to identify pathology when examining cadaveric lungs. Cadaveric lung specimens were arranged at six stations in the laboratory. For each specimen, students were asked to evaluate the organ and determine if the organ had any signs of pathology based on the specimen's gross anatomical characteristics. Half of the students used the provided pathology guide to assist them in their evaluation of the organ (experimental group) and half of the students had a laboratory guide that only included definitions of the pathologic terms (control group).

The control group scores were compared to the experimental group scores by performing a t-test using Graphpad Prism 6 software program. Effect size was estimated by calculating Cohen’s d. The internal consistency of the assessment was determined by calculating KR-20.

Results

The group using the pathology guide, overall, had a higher average percentage of items correct than the control group with a medium effect size for both comparisons (p < .001; Figure 6). For the nursing student population, the control group had 42.2% correct compared to 50.8% in the experimental group. For the medical student population, the control group had 47.3% correct compared to 55.6% in the experimental group. The internal consistency of the assessment was calculated and was KR-20 = 0.50, which is a good level for an instructor made assessment.

![Graph showing assessment scores for nursing and medical student population. In both populations, the experimental group was significantly higher than the control group, p<0.01. Values represent the percent of the total number of questions the student got correct.](image)

Figure 6. Assessment scores for nursing and medical student population.
Discussion
After the anatomic evaluation of cadaveric lungs, pneumonia, neoplasms, emphysema, chronic bronchitis and diffuse interstitial lung disease were the most commonly observed pathologic incidences. This differs slightly from another large-scale account of pathologic lesions in the gross anatomy laboratory, where tuberculosis was the most commonly found lesion (76% of cadavers; Geldenhuys et al. 2016). There was only one case of tuberculosis within our specimens, which represented less than 1%. The main discrepancy between these findings may be regional, since the other anatomical survey was performed on a cadaver population in Western Cape, South Africa. Bronchopneumonia and emphysema was also commonly found in the cadaver population in South Africa (over 45% for each condition), as well as our population here in New Orleans, Louisiana (35% and 53% respectively). There has also been a similar prevalence of anthracosis reported in the South Africa population as in the Louisiana population.

The authors suggest that the high amount of pulmonary edema observed in this study is most likely due to embalming artifact although they did not report how many cadavers that had edema also had pathology (Geldenhuys et al. 2016).

Descriptive accounts of the specific pathologic lesions discovered in embalmed cadaver lung populations include the presence of: pulmonary fibrosis, chronic obstructive pulmonary disease, pneumonia, squamous cell carcinoma and chondro-sarcoma of lung, pleural adhesions, old tuberculosis and lung metastasis (Wood et al. 2010 and 2015). We found these lesions to be detectable in our Louisiana based cadaver population.

Discoloration of the parenchyma and edema were the most commonly observed artifacts from the embalming process observed in our cadavers as well as the Western Cape population of South Africa (Geldenhuys et al. 2016).

After creating the pathology guide for the students, the implementation of a short assessment to determine if the guide could assist a user in identifying pathology revealed that even short term use (20 minutes) significantly increased student ability to identify pathologic lesions in a cadaveric lung. This finding is a little surprising, considering that the skill of palpation is purely a psychomotor skill that heavily relies upon the ability to feel differences in tissue density. Although the guide only provided photographs and verbal descriptions of the technique, the students were still able to detect differences from trying the maneuver for the first time. Informal feedback from the students was very positive regarding the utility of the pathology guide. This was similar to the feedback that was received during the content validation process.

Conclusion
There are several common pathologic lesions that can be detected grossly in an embalmed cadaver population. Students and faculty could use these instances as learning opportunities to complement the teaching of the anatomical sciences. These integrative learning opportunities may also be a way to deepen the impact that the willed body donor has on the health professional field.

The authors would like to acknowledge the individuals who donated their bodies for the advancement of science. Their contribution made the development of these resources possible.

The Cadaver Lung PG guide is freely available for download on LSUHSC's website at: http://virtualhumanembryo.lsuhsc.edu/GIFT/PathGuides%20-%20Copy.html.

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Literature cited


Bring Your Own Device Initiative to Improve Engagement and Performance in Human Anatomy and Physiology I and II Laboratories

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Abstract
In an informal survey, just 4.93% (2014) and 6% (2015) of Human Anatomy and Physiology students stated that their favorite lab activity was using a microscope. Additionally, performance on lab practical microscopy questions was low with the average percent correct between 31.85% and 41.94%. To increase student interest, engagement and performance, we purchased microscope adapters that allow students to take photomicrographs with their smartphones. Likert surveys were used to assess student engagement, and the percent of correct answers on histology questions on lab practicals. Comparisons were made between semesters where adapters were used and not used. Results show that lab practical scores were higher in semesters where microscope adapters were used compared to semesters where they were not used, but the increase in student performance was not significant. The use of smartphones along with microscope adapters has the potential to improve student engagement, but the role that smartphones play in student performance is unclear. doi: 10.21692/haps.2018.004

Key words: smartphones, BYOD, histology, laboratory education

Introduction
Smartphones are mobile phones that have advanced connectivity options such as Wi-Fi and web-browsing capability as well as sophisticated computing abilities and built-in applications (Soikkeli et al. 2013, Chan et al. 2014). Ownership of smartphones among adults has increased over the past years (Falaki et al. 2010, Soikkeli et al. 2013) with ownership rates rising from 35% to 68% between 2011 and 2015 (Anderson 2015). Smartphones are convenient technological tools for learning in terms of portability, affordability, accessibility, operability, and applicability (Kafyulilo 2012). Through “Bring Your Own Device” (BYOD) initiatives, educators are starting to incorporate students’ mobile technology including smartphones into the classroom curriculum (Kiger and Herro 2015). However, little research has been done to examine how the utilization of smartphones in the laboratory impacts learning outcomes, particularly in a science laboratory.

The increased ubiquity of mobile devices such as smartphones on college campuses allows for new instructional strategies for higher education students (Gikas and Grant 2013), but their implementation into academic institutions for learning purposes remains an ongoing debate. BYOD appears to be gaining acceptance in K-12 school districts (Burns-Sardone 2014), but it is still not universally supported. It has been found that there is a significant difference between the age of the instructor and support of using mobile phones in the classroom, with those over age 50 being less accepting than those who are aged 33-49 or are less than 32 years of age (O’Bannon and Thomas 2014). Instructors may also be hesitant to incorporate technology into their classrooms because, according to Gikas and Grant (2013), there is little research regarding how these tools are being used for teaching and learning purposes, especially by university students.

Using microscopes to study biological tissues (i.e. histology) is a particularly challenging skill for students in Human Anatomy and Physiology at the University of Mississippi. In the fall of 2014, 59.18% of students responding to an informal, opinion survey stated that the most difficult part of learning tissues was remembering what the tissues looked like. In additional informal surveys, the percentage of students who stated that their favorite lab activity was using the microscopes was 4.93% in 2014 and 6% in 2015. In addition, performance on lab practical questions involving the identification of specimens under a microscope is poor, with the average percent correct as low as 31.85% and no higher than 41.94%. These numbers are troubling because Human Anatomy and Physiology I and II are required courses for students desiring entry into many allied health professions (e.g. nursing, occupational therapist, physician assistant, etc.) where knowledge of tissues, obtaining samples for biopsy, and interpreting microscopic specimens are critical to job performance. Nivala et al. (2013) found that students’ prior histological knowledge is a predictor of medical student performance in diagnostic pathology, confirming the value of having a strong background in the basic medical sciences.

According to Morrison and Gardner (2015), the first time a mobile phone was used to capture a microscopic image occurred in 2009. Students currently use their mobile phones...
to try to take pictures of microscope slides by holding their phone's camera lens over the ocular lens of the microscope. It is difficult to get the focal point of the phone's camera lens and the ocular lens of the microscope to properly align with this technique however, and according to Morrison and Gardner (2015), it requires “practice, patience, and a steady hand.” In 2012 companies started manufacturing accessories such as microscope adapters which attach smartphones to a microscope allowing students to take high quality pictures through the microscope by aligning focal points of both lenses (Morrison and Gardner 2015).

In recent years, United States governmental agencies have called for the transformation of undergraduate STEM (science, technology, engineering, and mathematics) courses to include active learning in the classroom (Shaffer 2016). In addition, the Vision and Change report from the American Association for the Advancement of Science (2011) suggests that active learning methods in the classroom should be implemented to increase student performance in undergraduate life science courses. High structure course methods involving active learning have been shown to increase student engagement and performance (Shaffer 2016) and using smartphones in the laboratory along with microscope adapters may allow for the same effects by increasing self-motivation. Sturges et al. (2016) have shown a significant relationship between student GPA, the number of hours of studying students reported, overall self-reported motivation, and academic performance in undergraduate Human Anatomy and Physiology courses.

Use of mobile devices in the laboratory could improve student engagement within the laboratory, expand the learning environment, and promote the productiveness of faculty and students (Dahlstrom 2013). Allowing students to photograph microscope slides with their phones may enhance student confidence that they have the information they need to study for the histology questions on exams. Student confidence may increase the amount of self-efficacy students have when it comes to answering those questions. Solberg (2012) showed that self-efficacy could translate into improved performance and learning outcomes because of higher confidence levels. Additionally, the convenience of having their own photomicrographs on their device may motivate students and encourage them to spend more time studying. The convenience and flexibility of smartphones provide opportunities for students to collaborate with classmates and access course material regardless of their location (Traxler 2007, Kafyuliilo 2012, Gikas and Grant 2013). Students who spend more time studying material that will be on the lab practical do better on lab practical exams (Cogdell et al. 2012).

Some concerns associated with allowing students to use their mobile phones in the classroom include device theft, security, equity, distractions, and inappropriate use of the device (Hartnell-Young et al. 2008, Kafyuliilo 2012, Thomas et al. 2014, Kiger and Herro 2015). These concerns, however, do not pertain to college students who are the focus of this study. Kafyuliilo (2012) also stated that effective ways to “subdue the negatives and promote the positives” of smartphones should be found because the benefits of using smartphones in the classroom seem to outweigh the drawbacks. When implementing BYOD policies, the ease of using smartphones for laboratory teaching purposes does not necessarily make them appropriate and effective, pedagogically (referring to the method and practice of teaching children; Kiger and Herro, 2015) or andragogically (referring to the method and practice of teaching adult learners).

The purpose of our study is to provide an evidence-based resource for educators considering implementing the use of student smartphones and mobile devices in the laboratory. Our hypothesis is that use of microscope adapters with student smartphones will improve student engagement in the laboratory and performance on histology-based questions on lab practicals. This study will serve as a resource in the debate of curricular incorporation of smartphones and will help inform educators, schools, and universities about the effects of incorporating smartphones into the laboratory for learning purposes.

Materials and Methods
Five hundred and fifty-six students enrolled in Human Anatomy and Physiology I (BISC 206) and II (BISC 207) at the University of Mississippi were recruited to participate in this study. Anatomy and Physiology I and II represent a two-semester course sequence in which students must successfully complete Anatomy and Physiology I (with a C or better) before taking Anatomy and Physiology II. At the University of Mississippi, Anatomy and Physiology I is only offered in the fall semesters with approximately 390 students enrolled in one lecture section and 13 lab sections. Anatomy and Physiology II is only offered in the spring semesters with approximately 250 students enrolled in one lecture section and 9-10 lab sections. All participants were typical undergraduate college students ranging between the ages of 18 and 23 and varying in race and gender.

This study was incorporated into the histological portions of the laboratory sessions, but students were informed that involvement in this study was optional. Our protocol was approved as Exempt under 45 CFR 46.101(b) (#1 and 2) by the University of Mississippi Institutional Review Board (Protocol #16x-162). Students were not compensated in any way or awarded course credit for participation in the experiment. It is highly unlikely that any of these students were repeats since students in Anatomy and Physiology II in Spring 2016 had already passed Anatomy and Physiology I, and would therefore not enroll in Anatomy and Physiology I in Fall 2016.

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Sixteen universal microscope adapters [Carson Hookupz™ (IS-100) Universal Smartphone Optics Adapter from Carson Optics] were purchased for this study. These adapters allow students to take high quality pictures through the microscope with their mobile devices in the laboratory by aligning the focal points of the smartphone’s camera lens with the microscope’s ocular lens. This adapter was designed to fit most smartphones with or without phone cases including all iPhone models (except the iPhone 6 Plus), all Samsung Galaxy models, HTC One, HTC Evo 4G/4G LTE, LG G2, Motorola Moto X/G, Droid Razor, etc. (Carson Optics, 2016). With an outer eyepiece diameter of 20-58mm, this adapter was designed to fit 99% of all optics and is compatible with most microscopes, including slit lamp microscopes, binoculars, monoculars, endoscopes, etc. (Carson Optics, 2016). Other adapters were available at the time of purchase, but they were unable to fit multiple types and sizes of smartphones. For example, the Magnifi™ is an iPhone photoadapter case that was made to be compatible with only iPhones 4, 4s, 5, 5s, or SE, and it requires the user to remove their phone case to fit the adapter on the iPhone (Magnifi, 2016). Since completing this study, Carson Optical has developed the HookUpz™ 2.0 Universal smartphone optical adapter (IS-200) as well as adapters made to fit specific iPhone models (Carson Optics, 2017).

The microscope adapters were used in the laboratory during the Spring 2016 (Anatomy and Physiology II students) and Fall 2016 semesters (Anatomy and Physiology I students). Students were able to digitally capture microscopic images they found interesting as well as tissues and structures they needed to know and identify on the lab practical. These pictures could then be used by the student as a resource for study or shared with classmates via text message, social media, or email.

Two surveys were given to students each semester to assess the students’ level of interest and engagement with microscopy and tissue examination both before and after the use of the microscope adapters along with their smartphones. Survey questions were predominantly Likert-style and asked participants to give a rating from strongly agree to strongly disagree in response to each statement. The first survey was administered to the students in the laboratory at the beginning of the semester. Students were then given instructions on how to use the microscope adapter, how to hook up the smartphone to the microscope adapter, and how to hook up the adapter to the microscope lens. A short video from the Carson website showing how to use the microscope adapter was also shown to the students (CarsonOptical, 2014). Refresher instructions were given throughout the course as needed. Students used their smartphones along with the microscope adapters to take pictures of specimens under the microscope in several laboratory exercises throughout the semester. The second survey was given to students at the end of the semester after their last laboratory session involving the use of the microscope adapters along with their smartphones.

Aggregate performance (i.e. percent correct) on each histology question was calculated by dividing the number of correct responses for each histological lab practical question by the total number of student responses per question. For Anatomy and Physiology I, performance on the histology-based questions from each of the two lab practicals was compared between the Fall 2015 semester (microscope adapters were not used) and the Fall 2016 semester (microscope adapters were used). For Anatomy and Physiology II, performance was compared between the Spring 2015 semester (microscope adapters were not used) and the Spring 2016 semester (microscope adapters were used).

Performance data were analyzed using two-tailed t-tests assuming unequal variances. Chi-square analyses were performed for Likert-style and categorical survey questions. To examine differences in survey responses between low, medium, and high users of adapters, a one-way analysis of variance (ANOVA) tests were performed for questions asking the students to respond with a ranked rating from 1-10. The level of significance was set at alpha = 0.05 for all analyses. Statistical tests were performed using Microsoft Excel and StatPlus.

Results

Student Profiles

Enrollment data and survey responses show that most students enrolled in Human Anatomy and Physiology I and II were pursuing a career in an allied health profession (e.g. nursing, physical therapy, occupational therapy, dietetics, or physician assistant), with the most common majors being exercise science, a (2+2) or (3+1) allied health program such as nursing or occupational therapy, and dietetics and nutrition. All but two students owned some type of smartphone that allowed them to take pictures, and most students (257) reported having 16 gigabytes (GB) of memory available on their smartphone.
Figure 1. Human Anatomy and Physiology I (black bars) and II (gray bars) student responses regarding how they used the microscope adapters within their lab group.

Figure 2. Human Anatomy and Physiology II student ratings of how easy it was to take pictures with their smartphones through the microscope lens with the microscope adapter with 1 meaning it was very hard to take pictures and 10 meaning it was very easy to take pictures.
Figure 3. Human Anatomy and Physiology II student ratings of how easy it was to take pictures with their smartphones through the microscope lens with the microscope adapter with 1 meaning it was very hard to take pictures and 10 meaning it was very easy to take pictures.

Table 1. Student responses to Likert-style statements on the second survey (SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree; df = 4). *This question was only asked of Human A&P II students.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Course</th>
<th>Group</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>( \chi^2 )</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was easy to identify specimens under the microscope with the use of my smartphone and the microscope adapter.</td>
<td>Human A&amp;P II</td>
<td>Low Use</td>
<td>4</td>
<td>13</td>
<td>14</td>
<td>5</td>
<td>4</td>
<td>12.75</td>
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<td>28</td>
<td>21</td>
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<td>6</td>
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</tr>
<tr>
<td></td>
<td>High Use</td>
<td>11</td>
<td>27</td>
<td>14</td>
<td>12</td>
<td>5</td>
<td>19.04</td>
<td>p&lt;0.001</td>
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<td></td>
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<td>2</td>
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<td>5</td>
<td>5</td>
<td>2</td>
<td>5.727</td>
<td>p&lt;0.022</td>
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<tr>
<td></td>
<td>Medium Use</td>
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<td>75</td>
<td>46</td>
<td>31</td>
<td>9</td>
<td>75.39</td>
<td>p&lt;0.001</td>
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</tr>
<tr>
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<td>19</td>
<td>39</td>
<td>22</td>
<td>12</td>
<td>3</td>
<td>37.58</td>
<td>p&lt;0.001</td>
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<td>10</td>
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<td>5</td>
<td>2.056</td>
<td>p=0.726</td>
<td></td>
</tr>
<tr>
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<td>18</td>
<td>19</td>
<td>8</td>
<td>7.60</td>
<td>p&lt;0.01</td>
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<td>13</td>
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<td>19</td>
<td>14</td>
<td>7</td>
<td>5.710</td>
<td>p=0.222</td>
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<tr>
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<td>7</td>
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<td>3</td>
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<td>2</td>
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<td>54.66</td>
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<td>35.42</td>
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<tr>
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<td>1</td>
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<td>p=0.156</td>
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<td>125.8</td>
<td>p&lt;0.001</td>
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<tr>
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<td>70.53</td>
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<td>10</td>
<td>15</td>
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<td>2</td>
<td>15.39</td>
<td>p&lt;0.01</td>
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<tr>
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<td>6</td>
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<td>28</td>
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<td>21.87</td>
<td>p&lt;0.001</td>
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Bring Your Own Device Initiative to Improve Engagement and Performance in Human Anatomy and Physiology I and II Laboratories

Survey #1 Data

Students in Anatomy and Physiology II (spring 2016) had previously taken Anatomy and Physiology I where microscope adapters and smartphones were not available. Most (58%) of these students agreed with statements saying it was difficult to identify and study specimens under the microscope \( (X^2 = 132.6, df = 4, p<0.001) \) during the lab practicals in Anatomy and Physiology I \( (X^2 = 125, df = 4, p<0.001) \). Students in Anatomy and Physiology I (Fall 2016) were either new to the course or re-taking Anatomy and Physiology I from a previous year where microscope adapters and smartphones were not used in the laboratory. The Anatomy and Physiology I students were asked, “Have you ever used a microscope before,” and most (97.2%) said yes \( (X^2 = 310.6, df = 1, p<0.001) \). To gauge how much experience they had with using microscopes, they were asked to rate their experience with microscopes on a scale of 1 (low) - 10 (high); the most common rating was a 5 \( (X^2 = 117.5, df = 9, p<0.001) \).

Students in Anatomy and Physiology II overwhelmingly responded “yes” to the question “Have you ever tried to use your smartphone to take a picture through a microscope lens without a microscope adapter” \( (X^2 = 92.5, df = 1, p<0.001) \), while Anatomy and Physiology I students responded “no” to this question \( (X^2 = 72.6, df = 1, p<0.001) \). Those who responded “yes” to this question were asked to rate the quality of the pictures that were taken by their smartphones through a microscope lens without a microscope adapter, with 1 being very low quality and 10 being very high quality. For those in Anatomy and Physiology II, the most common rating was a 4 \( (X^2 = 69.2, df = 9, p<0.001) \). For students in Anatomy and Physiology I, the most common rating was a 5 \( (X^2 = 63.6, df = 9, p<0.001) \). For this question, responses of students in Anatomy and Physiology II did not significantly differ from responses of students in Anatomy and Physiology I \( f_{(205)} = 0.617, p = 0.528 \).

When responding to statements concerning student willingness to learn how to use something new to help them study tissues (e.g. using a microscope adapter with their smartphones to take pictures through a microscope), most students in both Anatomy and Physiology II (90.4%; \( X^2 = 213.5, df = 4, p<0.001 \)) and Anatomy and Physiology I (88.2%; \( X^2 = 432.2, df = 4, p<0.001 \)) either agreed or strongly agreed with these statements. In addition, most students in Anatomy and Physiology II (90.9%; \( X^2 = 214.3, df = 4, p<0.001 \)) and Anatomy and Physiology I (89.6%; \( X^2 = 487, df = 4, p<0.001 \)) agreed or strongly agreed with statements stating that they believe that using their smartphone as a learning tool in the laboratory will help improve their engagement in the laboratory and that using their smartphones along with a microscope adapter will make it easier to study specimens for the lab practicals.

Survey #2 Data

Students were asked how they used the adapters within their lab group. In Anatomy and Physiology II, most students claimed that they either took photos during every lab and shared them with their classmates, or they took only a few photos and contributed to sharing them with their classmates \( (X^2 = 180.6, df = 5, p<0.001; \) Figure 1). In Anatomy and Physiology I, most students claimed they took a few photographs and contributed to sharing them with their lab mates \( (X^2 = 477.2, df = 5, p<0.001; \) Figure 1). Students were classified and put into groups (low use=no photographs taken, medium use=“a few” photographs taken, and high use=photographs taken during every lab) based on their responses to this question for further data analysis.

Students were also asked to rate from 1-10 the quality of pictures that were taken by their smartphones through the microscope lens with the use of the microscope adapter. Ratings were most common in the upper half of the scale for both Anatomy and Physiology II and Anatomy and Physiology I with 8 being one of the most common responses. Ratings within the low, medium, and high use groups were not significantly different in Anatomy and Physiology II \( F_{(2,176)} = 0.367, p = 0.691 \) or Anatomy and Physiology I \( F_{(2,291)} = 0.883, p = 0.415 \). For the ranked rating of the ease of taking pictures with their smartphone with the microscope adapter, student responses within the low use, medium use, and high use groups were analyzed with a one-way ANOVA. Responses were dispersed across the entire scale for all groups in both Anatomy and Physiology II \( F_{(2,176)} = 0.389, p = 0.678 \) and Anatomy and Physiology I \( F_{(2,291)} = 0.267, p = 0.766 \) (Figure 3).

Most students in Anatomy and Physiology II and Anatomy and Physiology I significantly agreed that it was easy to identify specimens under the microscope using their smartphones and a microscope adapter for all groups except for the low use group in Anatomy and Physiology I (Table 1). More students in the medium use (Anatomy and Physiology II, Anatomy and Physiology I) and high use (Anatomy and Physiology I) groups agreed that it was easy to take pictures using their smartphone and the microscope adapter (Table 1). In response to the ease of taking different pictures of the same specimen, only the majority of medium and high users in Anatomy and Physiology II and Anatomy and Physiology I agreed with the statement (Table 1).

For students in Anatomy and Physiology II and Anatomy and Physiology I, significantly more students in the medium use and high use groups agreed with statements saying they believed using their smartphone as a learning tool helped improve their performance and engagement in the laboratory (Table 1). Significantly more students in the low use group were neutral towards the statement that said they believed using their smartphone helped improve their engagement (Anatomy and Physiology I and Anatomy and Physiology II) and performance (Anatomy and Physiology I) in the laboratory (Table 1). Within all usage groups, more students in Anatomy and Physiology II were neutral to the statement

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saying they believe using their smartphone with the adapter to take pictures made it easier to study specimens for the lab practicals (Table 1). Lastly, significantly more students in the low and medium use groups (Anatomy and Physiology II) and medium and high use groups (Anatomy and Physiology I) were neutral towards the statement that they like laboratory exercises that involve microscopes more because of the use of smartphones as a learning tool (Table 1). Significantly more students in the high use group (Anatomy and Physiology II) agreed with this statement (while significantly more students in the low use group (Anatomy and Physiology I) disagreed with it (Table 1).

Lab Practical Data
In Anatomy and Physiology II, average percent correct on histology-based questions from the first lab practical increased from 41.1% in Spring 2015 to 58.63% in Spring 2016, but this increase was not significant \(t(7) = 2.17, p = 0.067\). For the second lab practical, scores decreased, 41.94% in Spring 2015 to 35.98% in Spring 2016, but not significantly \(t(10) = 0.455\). When both lab practicals were combined, there was a slight, but not significant, increase for the Spring 2016 semester with the average percent correct on lab practical questions being 45.42% compared to 41.66% in Spring 2015 \(t(122) = 0.587; p = 0.563\).

In Anatomy and Physiology I, there was a slight, but not significant, increase in scores on the first lab practical during the Fall 2016 semester with an average percent correct of 42.29% on histological questions on the lab practical compared to the Fall 2015 semester whose average percent correct was 33.71\% \(t(10) = 1.52, p = 0.159\). When both lab practicals were combined, there was a significant increase in lab practical scores with the average percent correct on lab practical questions rising from 31.85\% \(t(13) = 2.32, p = 0.038\). Lastly, there was no significant difference \(t(39) = 1.34; p = 0.190\) in performance on histology-based questions between 2016 students (44.07\% correct, adapters used) and 2015 students (38.25\% correct, adapters not used).

Discussion
Student Profiles and Engagement
Device equity was not a concern for the incorporation of smartphones in the laboratory in this study because almost all students owned some type of smartphone that allowed them to take pictures. Furthermore, it ensures that the prevalence of student mobile devices and technology offers an opportunity for schools and educators to use these devices for instructional purposes (Kiger and Herro 2015). Additionally most students have had some experience with microscopes prior to using the microscope adapters along with their smartphones. Familiarity and experience with using microscopes may have helped students to set up the microscope adapters onto the microscope.

Regarding their previous experiences, most Anatomy and Physiology II students significantly agreed that it was difficult to identify and study specimens under the microscope and responded that they tried to use their smartphones to take pictures of microscopic specimens without an adapter. These efforts led to pictures that were about average in terms of quality and students still admitted to having difficulty identifying specimens and studying for lab practicals. Most students in Anatomy and Physiology I, unlike those in Anatomy and Physiology II, had never tried to use their smartphone to take pictures of specimens through a microscope. For the few who had, the quality of pictures taken by their smartphones without a microscope adapter was average.

Similar to our results that showed that most students were willing to use something new in the laboratory to help them learn tissues, students in the Kafyulilo (2012) study felt comfortable learning with a mobile phone and thought that their use in the classroom could simplify learning and save time. Our students were optimistic about, and in favor of, the use of their smartphones with a microscope adapter as a tool to help them learn tissues and study for lab practicals. Students in the Brown et al. (2014) study similarly responded that they were willing to use response and engagement technology such as smartphones in the classroom to increase student engagement and that they desired to use technology in the classroom.

We a priori assumed that students would have varying levels of use with microscope adaptors. Our results show that not every student used the adapters to take photographs with their smartphone and not every student used the adapter during every lab. The effects on student performance and engagement may differ among students who responded differently to this question because students who never used the microscope adapters will have a different experience and responses than those who used their smartphones to take pictures with the microscope adapter for every laboratory exercise.

Usage patterns, however, were not consistent across Anatomy and Physiology II and Anatomy and Physiology I students. Ratings within each usage group were expected to be low for the low use group, medium for the medium use group, and high for the high use group. These expected patterns were not apparent for students in Anatomy and Physiology II. For Anatomy and Physiology I, however, students in the low use group did have low ratings, while students in the medium use group had middle ratings, and students in the high use group had high ratings. The differences within these groups were significant.

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The quality of the pictures taken with smartphones and microscope adapters were overall rated as above average, but this was not significant for students in Anatomy and Physiology II or Anatomy and Physiology I. It was expected that the rankings of the quality of pictures taken with a microscope adapter would be higher than those of the quality of pictures taken without a microscope adapter. When the students were asked to give their ratings of the picture quality, there was no reference for them to compare the quality to.

Since the microscope adapters are compatible with multiple types of smartphones and provide an alignment of the camera lens with the microscope lens for high quality pictures, we expected that most students would agree that it was easy to take pictures and identify microscopic specimens with the use of the adapter. However, the ranked ease of taking pictures was dispersed across the scale for all usage groups, and these results were not significant for both Anatomy and Physiology II and Anatomy and Physiology I. These results could be due to individual differences in microscope and microscope adapter experience. For example, those in the high use group who used the adapters during every lab may have gained skill with using them through practice and experience. Those in the low use group, however, may not have had enough experience working with the adapters to gain the practice needed to easily attach their smartphones. Most groups in Anatomy and Physiology II and Anatomy and Physiology I significantly agreed that it was easier to identify specimens with use of the microscope adapter indicating that smartphones have the potential to be beneficial learning tools.

A study done in Tanzania found that pre-service teachers, students, and college instructors were in favor of the use of mobile phones as a teaching and learning tool in the classroom (Kafyulilo 2012). In our study most students in the high use group for Anatomy and Physiology II significantly agreed that they liked laboratory exercises that involve microscopes more because of the use of smartphones as a learning tool. Students in the other groups for Anatomy and Physiology II and Anatomy and Physiology I either disagreed or were neutral towards this statement, which was not expected. However, these students who claimed they rarely took photographs in the laboratory with the adapters and their smartphones did not have much experience with the adapters, which could account for their responses. From the student engagement results, we conclude that students perceived that the use of smartphones in the laboratory helped improve engagement and performance in the laboratory, and that the use of smartphones along with microscope adapter to take pictures of specimens may make it easier for students to study for histological questions on lab practicals.

**Student Performance**

Even though lab practical scores were shown to have been higher in most semesters where smartphones and microscope adapters were incorporated into the classroom, the increase in scores was not significant across all semesters. In addition, scores on the second practical in Anatomy and Physiology II were lower in Spring 2016 where the adapters and smartphones were used in the laboratory compared to Spring 2015 where adapters and smartphones were not used. Due to our IRB approval of comparing aggregate scores among students, we were not able to track individual scores or monitor student use of the adapters. With a higher level of IRB approval, however, we hypothesize that those who use the adapters during every laboratory will perform better on the laboratory practicals than those who rarely use the microscope adapter. Even though students shared pictures among their lab mates, the act of finding and photographing the pictures may be the formative learning tool. In addition, students who did not engage in the laboratory exercises by taking the photos directly with their phones may not have received all necessary pictures taken during each laboratory. It must be noted that the lab practical questions between semesters differ in both their content and precise placement, which could have affected the results.

**Overall BYOD Effects**

Our results are in agreement with other studies that have shown that the use of mobile phones and smartphones in science laboratories increases student engagement. The Ostrin and Dushenkov (2016) study found that the introduction of mobile phones into the Anatomy and Physiology laboratory along with content-specific application software resulted in an increase in student engagement and enthusiasm in the material. Their students perceived that using mobile devices in the Anatomy and Physiology laboratory was enjoyable, was effective in motivating them to learn the material, and resulted in a positive learning experience overall.

In addition, Harper et al. (2015) found that the use of student smartphones to take pictures of microscope specimens in an undergraduate botany class enhanced student engagement, and students reported that taking their own images helped them make better connections with what they were learning. Benham et al. (2014) found that students who perceived more benefits from the use of mobile devices in the classroom and who had a desire to use them reported greater engagement in the classroom. Similarly, our results on student performance are in agreement with those of Ostrin and Dushenkov (2016) who were also unable to confirm that introducing mobile phones and digital technology into the classroom increased student learning and understanding of the material and Sung et al. (2015) who found that mobile devices can improve educational effects, but concluded that the actual impact of mobile learning needs to be further assessed.

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In conclusion, the role that microscope adapters play in student performance is unclear. BYOD can be an effective way of engaging students and incorporating smartphones into the classroom interaction (Imazeki 2014). However, continuous research is needed to determine if smartphones and mobile learning have a true impact on student’s learning (Gikas and Grant 2013).

**Modifications and Future Considerations for Laboratory Education**

We feel that static imagery of microscopic specimens does not take full use of the smartphone's capabilities. Rather than just capturing an image of a specimen under the microscope, a student could take a short video of the specimen on their phone. They could move the stage of the microscope around while the phone stays attached to the microscope so that the entire specimen can be viewed throughout the video. Taking a video would also allow the student to narrate facts about the specimen or tissue.

In addition, students can use different forms of social media such as the “GroupMe” application to share pictures taken with their lab group. Phone applications like “Snapchat” can allow the student to not only take a picture or video of the specimen, but also to write a caption, draw an arrow to a certain part of the specimen, and send the picture or video immediately to their lab group members. In addition, different types and brands of microscope adapters could be examined in future studies. Since most students had iPhones as their type of smartphone, it might have helped to have a digiscoping microscope adapter built specifically for iPhones.

**Acknowledgements**

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**Literature Cited**


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Bring Your Own Device Initiative to Improve Engagement and Performance in Human Anatomy and Physiology I and II Laboratories


Does the Quality of Student Crib Cards Influence Anatomy and Physiology Exam Performance?

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Abstract
This study examined the relationship between quality of student prepared crib cards and exam scores in Anatomy and Physiology I and II. We hypothesized that students with better quality crib cards would have higher exam scores. Measured crib card attributes were: number of sections, number of colors used, and amount of the card utilized. Two hundred fifty four crib cards from 118 students who took four exams in undergraduate Anatomy and Physiology I and II courses were analyzed. We found correlations between the amount of the crib card used and exam scores, and between the numbers of colors used on the crib card and exam scores. There was no correlation between the number of sections used on the crib card and exam scores. These results could be used to help students make better crib cards for Anatomy and Physiology exams. doi: 10.21692/haps.2018.005

Key words: undergraduate education, crib cards, cheat sheets, note cards, Anatomy and Physiology

Introduction
Some previous research studies demonstrated that the use of crib cards was successful in aiding students in their exams and showed a positive correlation between the use of crib cards and exam scores. (Dickson and Baur 2008, Drake et al. 1998, Gharib et al. 2012, McCaskey 2006, Raadt, 2012, Skidmore and Aagaard 2003, Visco et al. 2014, Whitley 1996). These studies compared exam results of students who used crib cards to exam results of students who were not allowed to use crib cards. Gharib et al. (2012) showed that those students who used crib cards did better on exams than those who did not use crib cards and that open book exams provided the biggest improvement in exam score. Skidmore and Aagaard (2004) found that the use of cheat sheets yielded improvement in exam performance and students who used cheat sheets did better on their exams than their non-using counterparts. Visco et al. (2014) found that the actual making of crib cards aided students in exam performance. They examined cards from ten engineering students and found that the making of the crib card improved exam performance as compared to when no crib card was made. Raadt (2012) found that students who prepared and used a cheat--sheet did significantly better on exams than those who did not. McCaskey (2006) found that the actual construction of the crib card or cribbing sheet and the content of the sheet improved exam performance but warned that other factors such as the amount of office hours attended also affected the results.

Conversely, other previous research studies found that crib cards were not useful to students. Dickson and Miller 2015, Erbe 2007, Hindman 1980, Trigwell 1987, and Whitley 1996) found that in undergraduate psychology courses there was no correlation between the ability to use a crib card and exam performance. Erbe (2007) found that there was a slight correlation between using a crib card and improved exam performance but after further analysis she concluded that the actual preparation of the crib card accounted for the improvement in exam scores when comparing pretest and posttest learning. She found that making the card contributed to the learning, not necessarily use of the card during the exam.

Crib cards may be useful in decreasing student anxiety during exams (Butler and Crouch 2011, Dickson and Baur 2008, Drake et al. 1998, and Trigwell 1987). These studies concluded that students were less anxious when they had a crib card versus when they did not, and when they had access to the crib cards they did better on the exam. Unfortunately Dickson and Bauer (2008) were not able to differentiate whether or not the card directly improved exam performance or if the improved exam performance was due to the decreased anxiety that occurred when students used crib cards.

Dickson and Baur (2008) theorized that students did not study as much as they did before or would have done before because students viewed the cheat sheet as a “crutch”. They found that students spent time making the cheat sheet and because they had the cheat sheet they did not do further studying, or spent half their usual time studying. For example, students stated that if they would usually study for five hours for an exam, when allowed to use the cheat sheets they only studied for two and a half hours.

Burns (2014) asked students to tally the number of times they used their crib cards during the exams. She found a negative correlation between the number of times students used their
crib cards and their exam scores. Moderate and low achieving students increased their dependency on their crib cards throughout the semester.

The hypothesis of this study was that the quality of the crib cards would correlate with student exam scores. Students who used critical thinking skills to select more important information and effectively organize it for retrieval during exams would have higher exam scores. If supported, this hypothesis could help explain the contradictions between those previously mentioned studies that found improvements in student performance using crib cards and those that showed no improvement.

**Methods**

Students from four Anatomy and Physiology classes were invited to participate in the study. One hundred and eighteen students participated with some students enrolled in both Anatomy and Physiology I and Anatomy and Physiology II. Composition of the classes was predominantly freshman (77%), followed by sophomores (18%), juniors (4%), and seniors (2%). The students’ majors were Exercise Science (34%), Nursing (33%), Athletic Training (18%), Biotechnology (6%), Liberal Studies (5%), and other majors: Education, Bioengineering, Physical Education and Psychology (4%).

Students followed directions for creating the crib cards that included: card size of three by five inches, hand written on one side only, student’s name on the back of the card, and no drawing or figures on the card. The students took exams utilizing their own crib cards. Exams consisted of multiple choice questions, short answer responses, open ending questions and diagram labeling questions. Each of the four classes had cards from two exams and a final. A total of six exams were analyzed. All participants signed an informed consent document for the use of their crib cards and exam scores. The cards were coded numerically to assure confidentiality. Data were stored on password protected computers. The Endicott College Institutional Review Board approved this study, IRB #200019 R0.

Two hundred and fifty four crib cards were collected from the 118 students. The cards were analyzed for content and organization by examining: the number of colors on the card, the amount of the notecard that was filled, and how many sections were created on the card. Each card was given a numerical rating on a scale of 1-4, whereby “1” indicated that the card was one fourth full and “4” indicated that the entire card was filled (see Figure 1 for sample crib cards). The number of colors used on the cards was also scored. For example, if a card contained red, blue and yellow ink it would get a designation of three in that category (see Figure 2 for sample crib cards). The number of sections created on the card was also evaluated. For example if someone had vocabulary words as well as bullet points they were awarded a “two” in the number of categories evaluation. If a person had a chart, bullet points and vocabulary words they would be given a three in category evaluation. Some examples of categories were: vocabulary words, bullet points, charts, and content categories such as “skin” and “bones” (see Figure 3 for sample crib cards). Analysis of crib cards was done prior to comparing card attributes to exam scores.

All data were recorded on excel spreadsheets. The excel Pearson Product Moment Correlation Coefficient was used to compare crib card attributes to exam scores. We chose a level of significance value, p<.05. We calculated critical correlation value using 252 degrees of freedom (n=254, n-2=degrees of freedom) for a two-tailed test.
Results
Results varied for the three crib card attributes we examined. The critical correlation value for a significance of p < 0.05 and using n-2, or 252 degrees of freedom for a two tailed test was r = 0.12. We found correlations between the amount of the card used and exam scores, and between the use of color and exam scores. There was no correlation between the number of sections used and exam scores.

The strongest correlation we found was between the amount of the crib card used and exam scores. There was an r-value of 0.30 with p = 0.00001. This suggests that students who take the time and effort to utilize more space on the crib card and include more information had better exam scores. The scatter plot (see Figure 4 for the graph) shows that the relationship.

A weaker but still significant relationship existed between the number of colors used on the crib card and exam scores. There was an r-value of 0.21 with p = 0.000757. This suggests that students who organized their material on the crib card by using more colors of pencil or ink had better exam scores. The scatter plot (see Figure 5 for the graph) shows that the relationship.

There was no correlation between the number of sections created and exam scores. The r value of r = 0.07 with p = 0.266363 was not significant given the critical correlation r value of r = 0.12. The scatter plot (see Figure 6 for the graph) shows a scattered distribution of exam scores.

Table 1: Results of Pearson Product Moment Correlations for Attributes of Crib Cards

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We noticed a trend with exam card attributes whereby most students (77%) who had more than one crib card, tended to improve the quality of their crib card over time. For example, a student who used only one color on their crib card for the first exam often used two or three colors on subsequent crib card construction.

Discussion
We hypothesized that students who spent more time creating and organizing their crib cards would have better exam scores than students who had poorly constructed crib cards. Our hypothesis was supported for students who utilized more space on their crib cards and students who used more colors to organize their crib cards. The hypothesis was rejected for students who created more section on their crib cards. This information could be used to help students make crib cards that will be more effective in achieving better exam scores.

Our results may help explain contradictions in the literature regarding the crib card effectiveness. While some studies found improvements in student performance using crib cards there are others that found no correlation. The variability in these results may be due to the quality of the crib card rather than the type of crib card created.
cards (Dickson and Baur 2008, Drake et al. 1998, Erbe 2007, Gharib et al. 2012, McCaskey 2012, Raadt, 2012, Skidmore and Aagaard 2003, Visco et al. 2007, Whitley 1996) other studies showed no such improvement (Dickson and Miller 2015, Hindman 1980, Trigwell 1987, and Whitley 1996). Perhaps, some of those different findings could be explained if the quality of student crib cards was examined. If most students who were included in a study produced high quality crib cards, then those studies may have shown improvements in performance, while studies where most students produced poor quality crib cards may not have demonstrated improved exam performance. However, there may be other explanations for the differences in the literature regarding the usefulness of crib cards. For example, we are not aware of any previous studies that were done on students in Anatomy and Physiology courses. Furthermore, some studies used a sample size of less than 50 students or anecdotal reports. (Burns 2014, Dickson and Baur 2008, Erbe 2007, and McCaskey 2012)

Follow up studies might examine the creative process by which students construct crib cards. How much time do students put into creating crib cards? Do they mostly work alone or with study partners? Results of future studies could assist students to sort and prioritize the increasing body of knowledge that pertains to Human Anatomy and Physiology.

### About the Authors

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Melissa G Almeida was a junior nursing student at Endicott College. She is a member of Phi Sigma and the National Biological Sciences Honor Society. She is planning to pursue a graduate degree in nursing education.

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<th>Limited to</th>
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<tr>
<td>Limitations</td>
<td>A limitation to our study is the variability in the student’s ability to prepare crib cards. Some students may have had experience constructing crib cards in prior courses before taking Anatomy and Physiology I and II. Also, as we noted in our results, students tended to improve the quality of crib cards over time. The number of crib cards per student varied from two to six. Some students participated in the crib card study in only Anatomy and Physiology I but were in sections with other professors for Anatomy and Physiology II or vice versa. Therefore, some students had more opportunity to practice making crib cards. A further limitation was the variability among the six exams. While all exams included diagrams, short answer, and multiple-choice questions, the percentage of each type of question and length of each exam varied. Further, we had a few crib cards that were not usable, for example when a student forgot to put a name on the back of the card. Follow up studies might examine the creative process by which students construct crib cards. How much time do students put into creating crib cards? Do they mostly work alone or with study partners? Results of future studies could assist students to sort and prioritize the increasing body of knowledge that pertains to Human Anatomy and Physiology.</td>
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|                                 | Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT (2013) Improving students’ learning with effective learning techniques: Promising directions from cognitive and educational psychology. Psychological Science in the Public Interest, 14(1), 4-58 |

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Encouraging Student Participation in Peer-Led Discussion Sessions

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Abstract
Supplemental instruction using peer leaders can assist student learning in undergraduate STEM courses, but optional sessions are not well attended. This study compared attendance in peer leader sessions, nonproductive grade rates, and student evaluation data across two Human Anatomy and Physiology I courses in two different years. One course included peer leader session times that were posted at the start of the semester along with course schedules and incentives for attendance. In the other course, peer leader session times were scheduled after the start of the course without additional incentives for attendance. Incentivizing students and pre-planning peer leader sessions was associated with 70.4% of students attending at least ten weeks of peer leader sessions and a modest decrease in nonproductive grades. By comparison, 9.6% of students attended peer leader sessions in the course that lacked pre-scheduled sessions and student incentives. Future planning should include assessments of student learning and critical thinking associated with the peer leader program. doi: 10.21692/haps.2018.006

Key words: peer leader, supplemental instruction, peer-assisted learning

Introduction
Peer-supported learning, both structured and unstructured, can augment student learning in Human Anatomy and Physiology courses, but the optimal way to design such an environment remains unclear. Collaborative learning in universities gained momentum in the 1990s, highlighting the gains in student learning and comprehension (Bruffee 1999). Analysis of collaborative learning methods including supplemental instruction points to advantages including increased student engagement, ownership of individual learning, and better communication through interaction with peers. Caveats include effectively encouraging student participation and fostering equal contributions from individual students. Supplemental instruction includes using designated students, hereby referred to as peer leaders, to foster learning in the larger group.

Peer-assisted learning involves the use of students to facilitate learning comprehension and student success in a course. Peer leaders may be current or former (cross-year) students in the course, and the instructor chooses them before or at the beginning of the course (Topping 2005). Often, they attend course sessions and have access to notes and materials provided by the instructor. Peer-assisted learning has been linked to increased student performance and learning (Martin et al. 1994). Students report feeling comfortable approaching the peer leader and they are more willing to ask questions in sessions (Hensen and Shelley 2003). In cross-year peer leader settings, the enrolled students understand that the peer leader has successfully completed the course.

A growing number of STEM courses have implemented peer-assisted learning over the past two decades. The approach is well established in mathematics, chemistry, and physics courses at the undergraduate level (Hensen and Shelley 2003 and Evans et al. 2001). A growing number of medical schools use supplemental instruction and report gains in medical licensing exams. (Sobral 2002, Blanc and Martin 1994). Interestingly, supplemental instruction in human anatomy and physiology courses is not as widely reported compared to other STEM fields, though studies have indicated student success and learning gains in undergraduate biology courses (Rath et al. 2007 and Tenney and Houck 2003). Given the collaborative design in human anatomy and physiology laboratory courses, peer leader programs seem to be a natural fit.

The design of a peer leader program varies, and several considerations should be made prior to program implementation. Instructors may choose to provide more in-depth materials to cross-year peer leaders. The peer leader sessions may vary widely in their design and logistics. The instructor should be involved at some level in creating and approving the format of sessions. Sessions that are primarily question-and-answer in design often have the drawback of few students asking questions (or the same student asking all of the questions). The result can be a shortened session with students in attendance feeling frustrated that the experience did not add to their success in the class or knowledge of the content. Periodically, the instructor, peer leader, and students should evaluate the session format.
Considerations for the peer leader program include:

- Are the sessions mandatory for enrolled students?
- Who determines the format of the sessions?
- Is there a structured component to the session?
- What is the goal of each session?
- What is the ratio of peer leaders to students?
- How are the sessions scheduled?
- What type of room is the session held in? Will the peer leader have access to media and technology in that room? Does the room easily accommodate students working in groups?
- Who is responsible for logistics and notifying students of a change in the sessions?
- If attendance is taken, what is the protocol? How are attendance sheets or files collected and stored?

Peer leaders harness time in or out of class to lead sessions for the enrolled students. Sessions held immediately after class are often better attended, as long as many of the students do not have another class at that time. Sessions should be offered multiple times during the week in order to accommodate varying schedules. A weekly meeting of the peer leader and the instructor is a helpful component. The purpose of the meetings is three-fold. One, these meetings promote collegiality between the instructor and peer leader, especially important if the two people do not know each other well. Two, the meetings allow for better understanding of the material through discussion. Three, the meetings provides a time for the peer leader to share feedback and problems noted in the sessions. The peer leader should be compensated (monetarily or with academic credit) for sessions, meeting times, class attendance, and preparation time.

I first implemented peer leaders in Human Anatomy and Physiology courses through a STEM mini grant offered by my institution. Columbus State University, located in Columbus, GA, is a public, regional university with an approximate enrollment of 8200 students. The Human Anatomy and Physiology two-course sequence is required for three separate degrees and is offered every semester including a summer term. Each year, we offer ten to eleven sections (24 students per lab section) of Human Anatomy and Physiology I and seven to eight sections of Human Anatomy and Physiology II. These courses are taught as combined lecture sessions (72-168 students) and divided into smaller sections for labs (24 students/lab). On average, half of the Human Anatomy and Physiology I students earn non-productive grades (D/F/WF). A student must earn a C or better in Human Anatomy and Physiology I to enroll in Human Anatomy and Physiology II.

I began measuring the success of the program by looking at peer leader session attendance rates and final grade performance. Students with modest or above average attendance at these sessions had a higher final course average than students who attended sporadically or did not at all (Hughes 2011). Were the students who attended frequently more likely to succeed, regardless of session attendance? Did attending the sessions have a positive effect on student learning? What supplemental instruction has measured benefits? Other studies report that the higher performing students are more likely to attend sessions, thus skewing course average data (Jensen and Moore 2009).

One step towards answering these questions is to examine the motivation for participating in the sessions. The persistent problem with the peer leader program was low attendance. The sessions were optional for the enrolled students. I began the course by casually polling the students as to which meeting times would be best. I then gravitated to online polling sites to find the best times. I also encouraged students to approach the peer leader to find an alternate time if they were unable to attend meetings. Even though multiple sessions were offered weekly, attendance remained at or below ten percent. Given the success of students who attended the sessions, coupled with the pressure to justify the cost of the program, why did more students not attend?

The final course evaluation at the end of each semester included a prompt that asked students to comment on why they did not attend more sessions. The number one response was that the times did not fit into their schedules. This reason persisted even when the instructor and peer leaders encouraged students to contact them with available times for alternate sessions. Thus, the peer leader program modifications focused on encouraging student participation in the sessions. Would offering an incentive to attend the peer leader sessions and including session information prior to course registration increase the peer leader session attendance? This study was designed to evaluate the effects of incentivizing and pre-posting session times on the attendance rates, nonproductive grade percentages, and student evaluations of the peer leader program in Human Anatomy and Physiology I.

Methods
Participants and Planning
Participants included students enrolled in Human Anatomy and Physiology I at Columbus State University referred henceforth as Year I (120 students) and Year 2 (95 students) and the peer leaders (two per semester) for these two courses. Anatomy and Physiology I is a degree requirement for students majoring in Exercise Science, Health Science, and Nursing. Students across campus who are applying to graduate-level professional programs including dental, medical, and pharmacy schools also take the course. Course concepts
included chemistry, cell structure, genetics, histology, and human organ systems including integumentary, skeletal, muscular, neural, and special senses. The prerequisite for Human Anatomy and Physiology I is an introductory chemistry course with a C or better.

I was the instructor for both Year I and Year 2 courses, and I hired the peer leaders prior at the start of the semester. Peer leaders were selected based on their success in the Human Anatomy and Physiology courses as well as their willingness to foster student learning through planned sessions. The Institutional Review Board of Columbus State University approved this project (IRB #13-029, Year I; IRB #12-030, Year 2). Informed consent was obtained from all participants and student identities were protected in the analyses.

Three to four peer leader sessions were offered every week during the Year I and Year 2 courses. Weekly session times during Year I were based on student responses to an online poll during the first week of class. During Year 2, the session times were pre-arranged and disseminated to the students prior to the start of the semester. Course schedules are posted online during the previous semester; so advanced planning was necessary to inform students of the session times in Year 2. The following language was used online directly underneath the Year 2 class meeting schedule:

*Students will be expected to attend one of the weekly discussion sessions: (days/times listed)*

By pre-posting the session schedule in Year 2, students were able to plan around other course and work schedules prior to the start of the semester. I reminded the students of the session times throughout the semester, and I asked any students who could not make any weekly sessions to contact me the first week to potentially add an additional weekly session based on demand. If a scheduled weekly session did not have attendees, the session time was adjusted to serve the maximum number of students.

Earned credit through session attendance differed across Years I and 2. Students who attended one weekly session earned one-half point extra credit towards course points during Year 2. Students who attended more than one weekly session did not earn additional credit. Attending a session each week resulted in seven extra credit points towards 730 total course points in Year 2. I awarded no additional credit to students who attended peer leader sessions in Year I. The peer leaders were responsible for taking attendance at all sessions using rosters I provided them.

**Discussion session format**
Each discussion session led by the peer leader was limited to one hour and held in an available classroom with a computer station and projector system. I planned the format of each weekly session and created the handouts and activity sheets. I met with the peer leader each week to get feedback, answer questions, and go over the next activity. The discussion sessions during Years I and 2 included structured activities with included time for questions at the end of each session. The structured activities across Years I and 2 remained the same with only minor editing of worksheets and resources.

**Data collection and analysis**
Course grades, peer leader session attendance, and supplemental student evaluations were collected, compiled and analyzed at the end of each term. The supplemental evaluation included questions specifically directed at the peer leader program that were scored on a Likert scale. Averages and standard deviations of these data were calculated and reported. A t-test was performed on the student responses to determine statistical significance using the 95% confidence interval.

**Results**

**Attendance**

Figure 1 shows Human Anatomy and Physiology I semester attendance data from Year I and 2 courses. Prescheduled sessions and extra credit from session attendance were only in Year 2. The average number (+/- SD) of peer leader sessions attended during the course was significantly higher in Year 2 compared to Year I (11.0+/-0.5 vs. 3.5+/-0.5, p<0.0001). Figure 2 compares Year I to Year 2 based on session attendance categories. In Year I, 73.1% of enrolled students attended
fewer than five sessions during the course. In contrast, only 11.4% of students in Year 2 attended fewer than five sessions. Students attending at least ten sessions during the course increased from 9.6% in Year 1 to 70.4% in Year 2.

**Nonproductive Grades**

Figure 3 shows the percentage of nonproductive grades in Human Anatomy and Physiology I in both years. Nonproductive grades are D, F, and WF. A grade of C or better is required for admittance into the university’s Human Anatomy and Physiology II course. The percentage of students earning a nonproductive grade at the end of the course was 47% and 40.6% in Year 1 and Year 2, respectively.

**Peer Leader Student Evaluation**

Table 1 outlines the end-of-course survey results of the peer leader program by the enrolled students. The evaluations were anonymous, and the students earned credit by initialing the roster after submitting the evaluation. The same evaluation questions were used Year 1 and Year 2. All questions were scored on a one to five Likert Scale. The average scores of the responses ranged from 3.8-4.7 across the two years. None of the average scores for the questions decreased in Year 2 compared to Year 1. The average response score significantly increased from Year 1 to Year 2 in response to the following questions:

- The peer leader is knowledgeable of the course material.
- The peer leader does a good job of answering questions.
- The peer leader helps me understand the course material.
- I feel comfortable asking the peer leader for help.

Figure 2. Distribution of peer leader session attendance throughout the course. The percentage of students attending 0-4 (blue), 5-9 (red), 10-14 (green), and 15+ (purple) sessions are included for Year 1 (top) and Year 2 (bottom).

Figure 3. The percentage of students in Human Anatomy and Physiology courses earning a nonproductive grade (D, F, WF) at the end of the course. Year 2 included pre-posting peer leader session times and awarding extra credit for session attendance.

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Discussion
Peer leader session attendance significantly increased in Year 2, while the nonproductive final grade percentage decreased modestly. Low attendance in peer leader sessions had been a consistent problem in former years. Several attempts to increase attendance, including online polls to schedule session times, in-class reminders, and structured activities were not effective in increasing student attendance. Results from this study indicate that including session times in the schedule and awarding extra credit were positive actions to correct the attendance problem. Given that both changes were made in the same year, the relative impact of each is unknown.

In addition, other variables may have contributed to the attendance shift. Pre-scheduling the sessions and posting the times on the university’s course schedule link allowed the students to plan the schedule for that semester based on the session offerings. A few students emailed me prior to the start of the semester; concerned they could not find a session time that fit with their schedules. I explained that an additional weekly session would be added at the start of the semester; concerned they could not find a session time that fit with their schedules. I explained that an additional weekly session would be added at the start of the semester based on student feedback. The extra credit earned by attending a weekly session was likely highly sought out by many students. For example, students asked me throughout the semester when and how the session attendance extra credit would be added to their average. Thus, I surmise that the combination of these two changes led to the significant increase in session attendance in Year 2 vs. Year 1.

Positive student responses to several prompts in the end-of-course supplemental evaluation significantly increased in Year 2 compared to Year 1. The prompts included statements about the peer leader’s knowledge of the material and assistance in helping students understand the material. The reason for this change is unknown, though possible contributing factors may include the effectiveness of the individual peer leader. A peer leader in one course may develop a stronger connection to the enrolled students compared to the pairing in another semester. Interestingly, this connection may drive an uptick in session attendance. Alternately, the increase in session attendance may positively influence the peer leader evaluation. Evaluating student responses and attendance over subsequent years would help discern the relative influence of the individual peer leader.

In peer leader meetings with structured sessions, the students worked on activities designed by the instructor to supplement learning in areas in which students traditionally struggle. This form of supplemental instruction is associated with increased student learning and retention (Dawson et al. 2014). Areas of particular focus in Human Anatomy and Physiology I included molecular bonding, molarity, genetics, histology, and ossification. The sessions provided more structured time to think about the course material and ask questions, helping to resolve misconceptions. One caveat to incentivizing session attendance is an increase in the number of unengaged students in the sessions, potentially distracting other students. This situation underlies the importance of communication between the instructor and peer leader including discussing strategies to encourage active student engagement.

It is important to assess the degree to which peer leader sessions impact student understanding. Which activities and approaches are most helpful? What critical thinking assessment can be employed at the beginning and end of a session to gauge effectiveness? What improvements do the peer leaders suggest? What is the optimal way to recruit and train effective peer leaders?

Careful design and consideration should continue to be assessed and optimized, leaning on best practices in teaching and learning (Topping 2005). Supplemental instruction in STEM courses continues to advance in both undergraduate and professional programs (Dawson et al. 2014). While peer-reviewed studies on the impact of supplemental instruction

<table>
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<tr>
<th>Question</th>
<th>Year 1 AVG</th>
<th>Year 1 SD</th>
<th>Year 2 AVG</th>
<th>Year 2 SD</th>
<th>p value</th>
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<tbody>
<tr>
<td>The peer leader is knowledgeable of the course material.</td>
<td>4.3</td>
<td>0.7</td>
<td>4.6</td>
<td>0.6</td>
<td>0.003*</td>
</tr>
<tr>
<td>The peer leader does a good job of answering questions.</td>
<td>4.3</td>
<td>0.8</td>
<td>4.6</td>
<td>0.6</td>
<td>0.05*</td>
</tr>
<tr>
<td>The peer leader helps me understand the course material.</td>
<td>4.2</td>
<td>0.8</td>
<td>4.5</td>
<td>0.7</td>
<td>0.04*</td>
</tr>
<tr>
<td>The peer leader provides tools to help me learn the course material.</td>
<td>4.2</td>
<td>0.8</td>
<td>4.4</td>
<td>0.8</td>
<td>0.26</td>
</tr>
<tr>
<td>I feel comfortable asking the peer leader for help.</td>
<td>4.3</td>
<td>0.8</td>
<td>4.6</td>
<td>0.6</td>
<td>0.05*</td>
</tr>
<tr>
<td>I am more confident about the exam(s) after attending a peer leader session.</td>
<td>3.8</td>
<td>1.0</td>
<td>3.9</td>
<td>1.0</td>
<td>0.90</td>
</tr>
<tr>
<td>I am more prepared for the exam(s) after attending a peer leader session.</td>
<td>4.0</td>
<td>1.0</td>
<td>3.9</td>
<td>1.0</td>
<td>0.68</td>
</tr>
<tr>
<td>I have developed a better understanding of the subject with the help of the peer leader.</td>
<td>4.0</td>
<td>0.8</td>
<td>4.1</td>
<td>1.0</td>
<td>0.71</td>
</tr>
<tr>
<td>Based on my experience, I would encourage other students to engage in peer leader activities.</td>
<td>4.3</td>
<td>0.8</td>
<td>4.4</td>
<td>0.9</td>
<td>0.50</td>
</tr>
<tr>
<td>I recommend the BIOL 2221 cross-year peer-assisted learning program continue in future semesters.</td>
<td>4.5</td>
<td>0.8</td>
<td>4.7</td>
<td>0.6</td>
<td>0.23</td>
</tr>
<tr>
<td>I welcome the implementation of peer leaders in other courses.</td>
<td>4.5</td>
<td>0.7</td>
<td>4.7</td>
<td>0.7</td>
<td>0.27</td>
</tr>
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Table 1. Peer leader program evaluation results. Enrolled students submitted anonymous evaluations at the end of the course that prompted students to mark each question using the five-point Liekert scale, where 0=no opinion, 1=strongly disagree, 2=disagree, 3=undecided, 4=agree, and 5=strongly agree. Averages +/- SD were calculated for each question each year, and Student’s t test was computed for each question. * indicates Year 1 and Year 2 results were significantly different (p<0.05).
in mathematics, chemistry, and physics undergraduate course are numerous, supplemental instruction in Human Anatomy and Physiology course design is a congruent opportunity. If sessions are optional, posting the meeting times along with the course schedule and including incentives can effectively incentivize participation. Moving forward, Human Anatomy and Physiology instructors should continue to share problems and best practices in order to optimize peer leader programs.

About the Author
Dr. Kathleen (Katey) Hughes, Professor of Biology, has been a member of the Columbus State University (CSU) faculty since 2005. She earned a BS in Biology degree in 2000 from Winthrop University and a PhD in Biomedical Science (Department of Physiology and Functional Genomics) in 2004 from the University of Florida. She is the founder and director of CSU's Competitive Premedical Studies Program in CSU's College of Letters and Sciences. Dr. Hughes teaches a variety of courses at the undergraduate and graduate levels including Human Anatomy and Physiology, Neuroscience, Comparative Vertebrate Anatomy, Cell Biology, and General Biology.

Literature Cited

Exploring Student Perceptions of a Station-based Teaching Approach in The Human Anatomy and Physiology Laboratory

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Abstract
We adapted a station-based teaching approach (SBA) to teaching in the Human Anatomy and Physiology I Laboratory (Anatomy and Physiology). In the SBA students rotate through stations that are taught by the instructor or teaching assistant (TA). At each station students are presented with content using a teaching modality selected to maximize student engagement and encourage material application and integration. We surveyed students taught using the SBA approach and the independent study approach to assess student perceptions of the effectiveness of SBA method. Relative to the independent study, SBA improves student perceptions of their engagement, comfort level, and ability to apply material. The impact of TAs on student perceptions of SBA was also made evident in survey results. Overall, a SBA is beneficial for learning in the Anatomy and Physiology laboratory for students with diverse science backgrounds and majors. It is an effective teaching strategy that can be easily adapted to large and small classrooms, and for various topics. doi: 10.21692/haps.2018.007

Key words: anatomy pedagogy, station-based learning, small group learning, teaching assistants

Introduction
Human Anatomy and Physiology is a common pre-requisite for all healthcare-related professions. In many institutions, including ours, Anatomy and Physiology is a high enrollment course containing students from diverse science backgrounds. The Anatomy and Physiology course traditionally has a reputation for being extremely difficult, and many students start the semester very apprehensive. Students that enter our classrooms and laboratories often feel unprepared for the amount of information that they are expected to learn, understand, and apply. Many become overwhelmed by the sheer magnitude of new vocabulary and concepts that they are expected to retain. Student uneasiness may contribute to their overall course satisfaction, which is affected by factors like perceived learning effectiveness, learning community support, and perceived course learnability (Eagleton 2015). To help students become more engaged with the material, facilitate learning, reduce the stress typically associated with this course, and increase course satisfaction, we implemented a station-based teaching approach in the Anatomy and Physiology lab. As part of this implementation, we recruited and trained teaching assistants to help teach the stations.

Human Anatomy and Physiology at Elizabethtown College is a two-semester course. Anatomy and Physiology I is typically taught in the fall and focuses on the integumentary, nervous, and musculoskeletal systems. Anatomy and Physiology II is taught in spring, focusing on the cardiovascular, respiratory, renal, endocrine, and reproductive systems. Both courses have a lecture portion, split into two sections of approximately 45 students, and a laboratory portion that is divided into five sections of up to 18 students. Both lecture and lab meet twice a week, for 80 minutes. In the lecture, we use a physiology text (Human Physiology: An integrated approach, sixth edition by Silverthorn), and in lab we utilize an Anatomy Atlas (Atlas of Anatomy, second edition by Gilroy et al.) supplemented by an in-house instructions manual.

In Anatomy and Physiology I lab students study the skeletal system using real bones and plastic bone models. Muscles are studied by examining models, observing muscles on cadavers, and performing exercises and motions to understand functional anatomy. The Anatomy Atlas is used as a visual reference to support the hands-on materials. Each lab of 18 students has up to two teaching assistants (TAs) to assist the instructor. Thus, in every lab there are up to three individuals who are available to assist the students.

Anatomy and Physiology Students at Elizabethtown College
At Elizabethtown College, students in the Anatomy and Physiology course have highly diverse science backgrounds and varied majors (Table I). The only pre-requisite for this course is successful completion of General Biology I or Biology for non-majors. Anatomy and Physiology is a required course for occupational therapy and allied health majors. Occupational therapy students typically take Human Anatomy and Physiology in their sophomore year, after successfully completing General Biology I. Biology allied health majors, who include pre-physical therapy, pre-nursing, and pre-physician assistant students can take Anatomy and Physiology any time between their sophomore and senior years, although they most commonly take it in their sophomore or junior years.

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Station-Based Teaching

Until 2014, all students in the Anatomy and Physiology lab were responsible for learning all the required structures independently. They were provided with a list of structures they needed to know for the exam, along with descriptions of the structures to help with localizing the described bone markings. In the lab, students worked with bone specimens and were shown muscles on the cadaver. Outside of the lab, students were expected to memorize assigned muscles, along with the muscle origin, insertion, innervation, and action (also provided in a table of the in-house lab manual). While the instructor and the TA were always present during these lab sessions, they did not lecture. Their sole purpose was to help keep students on task and be available to address questions. Thus, in 2014 the main form of pedagogy utilized in the Human Anatomy and Physiology I lab at Elizabethtown College was independent study.

In 2015 and 2016 we began teaching Anatomy and Physiology I lab using the Station-Based Approach (SBA). In this approach, TAs and the lab instructor divide the course material into thematic stations and actively teach the material to smaller groups of students. Examples of the division of material by station are provided in Table 2. Throughout the lab, students rotate throughout stations, where they are taught by the instructor or a teaching assistant (TA). The instructor of each station utilizes a different teaching modality (bones, cadavers, physical exercises) to engage students in learning a particular section of the musculoskeletal system. We find that SBA is flexible, easy to implement using limited resources (varying TA support), and can be used to teach diverse topics of varying difficulty (Table 2).

Teaching assistants facilitate learning

Teaching assistants can be a valuable asset to course design and material delivery. Research has shown that students may benefit from integrated teaching methods involving use of TAs (Thomas et al. 2011).

In addition, teaching assistants can also serve as intermediaries between students and the instructor (Fig. I). Where students might not feel comfortable sharing information or posing questions to the instructor, they might find that asking TAs, who are closer to the students in age and taking similar classes, is easier and less intimidating. Similarly, through regular meetings with TAs, the professor has an opportunity to learn about common misconceptions that students have about the material, and challenges that might influence student progress in this course.

Furthermore, low achieving students might not be aware of effective learning techniques (Dunn-Lewis et al. 2016). By offering TAs as resources, we provide students with another opportunity to discuss effective learning strategies with their teaching assistants. At the beginning of the semester, when TAs introduce themselves to the students, they talk about how they studied for the course; reinforcing the importance of discipline, persistence, and planning. Since it is typical that a professor will advise not to cram the night before the exam, that suggestion carries little weight. However, when the same suggestion is stated by a fellow student who successfully
completed the course the year before, students in the course take it much more seriously. Furthermore, active involvement of TAs in the lab creates an atmosphere where successful completion of the course is possible, respected, and an accomplishment to emulate (Lockspeiser et al 2008). During the semester students have multiple opportunities to observe TAs while they teach their stations and answer questions, to reinforce confidence in the TA expertise and develop a relationship with the TA. This relationship helps create an atmosphere of support and encouragement that can help students improve academically (Eagleton 2015).

**Motivation for the study**
During the past 3 years, we have made extensive changes to the manner in which we teach the material in the Anatomy and Physiology I laboratory. We moved from complete independent study setup that was used for decades at the college to a stations-based approach to increase student engagement, comprehension, and overall course satisfaction. Our main goal in making these changes was to create an engaging course that prepares students for their major in the health profession, to present material in a way that promotes comprehension, critical thinking, and application, and develop a learning environment that is supportive and challenging for students of all science backgrounds. In this study, we assess student perceptions of the SBA method and increased TA engagement in the Anatomy and Physiology I laboratory.

**Materials and Methods**

**Institution information**
Elizabethtown College is a small private liberal arts college in a suburban community in central Pennsylvania. Its enrollment is 1,774 of which 38% are male and 62% are female.

**TA selection and training**
The training of TAs, which included explicit explanations of job expectations and regular TA meetings, was implemented when we started using the SBA method in 2015 and 2016. Teaching assistants are students who have successfully completed the two-semester Human Anatomy and Physiology sequence and have been selected through an application process. All prospective TAs sign a contract in which job expectations, appropriate code of conduct, and basic teaching suggestions are clearly stated. One of the most important expectations of all TAs is regular attendance at weekly TA meetings where TAs practice material they are assigned to teach for that week, discuss any issues or concerns they encountered during the week, and address any possible changes to the course content or schedule. Missing more than three meetings can be grounds for job termination. In addition, all TAs undergo mandatory lab safety training before the semester begins and throughout the semester, as the need arises. Once hired, TAs are provided with a manual to help them effectively fulfill the position demands. The manual includes a description of TA responsibilities, a code of conduct, a description of the procedure for properly handling specimens, teaching assignments, and a set-up guide for each lab station for the entire semester. At the end of the semester, students evaluate the TAs, and the TAs are given these evaluations as means of constructive feedback about their effectiveness as a TA.

Teaching assistants were not intentionally trained when the independent study method was used. They were not expected to teach; their only job was to help the instructor set up materials and answer student questions.

**Survey and data collection**
Students who took Anatomy and Physiology during 2014, 2015, and 2016 were invited via email to participate in a survey about their Anatomy and Physiology I lab experience (Tables 3 and 4). The survey was conducted online, via Survey Monkey during the spring of 2017. There was a difference between the two classes in the amount of time that had elapsed since they had taken the course that was targeted in this study; 2 years for students who had taken the course in 2014 and less than 6 months for those who took the course in the fall of 2016. All participation was completely voluntary and anonymous. The institutional review board of Elizabethtown College approved this project (IRB # 104925-1), and informed consent was obtained from all participants.

<table>
<thead>
<tr>
<th>Year Course Taken</th>
<th>Major Teaching Approach</th>
<th>Occupational Therapy</th>
<th>Allied Health</th>
<th>Other</th>
<th>Class Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Independent study</td>
<td>51</td>
<td>6</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>2015</td>
<td>Stations (SBA)</td>
<td>43</td>
<td>14</td>
<td>13</td>
<td>70</td>
</tr>
<tr>
<td>2016</td>
<td>Stations (SBA)</td>
<td>57</td>
<td>24</td>
<td>7</td>
<td>88</td>
</tr>
</tbody>
</table>

**Table 3. Breakdown of student participants by major and year**

The survey consisted of 22 qualitative questions and was divided into three main parts. The first portion of the survey collected factual information about when the students took Anatomy and Physiology lab, and what teaching method was utilized. The second part asked students to rate their experience in the lab, including questions about their perception of course quality. Students were asked to rate how challenging, stressful, interesting, and engaging they found the course. Finally, in the third portion of the survey, students were asked to rate the TAs on their professionalism, helpfulness, and knowledge. Options provided for responses...
were based on a 5-point Likert-based Scale. The survey did not ask for or collect any identifying information such as a student’s name or email address.

**Data analysis**

Survey responses were compared among the three years using a one-way ANOVA. Where differences were significant (p < 0.05), LSD post-hoc was used. Data from two respondents were excluded from analysis due to a mismatch between the year they took the Anatomy and Physiology lab and the manner in which the lab was taught (i.e. took the lab during the years it was taught using the SBA teaching approach, but reported using independent study method).

**Results**

Overall, 166 students participated in the survey (Tables 4).

**Evaluation of teaching method**

Students from all three years, regardless of teaching method either agreed, or strongly agreed that anatomy and physiology is important for their future career (Figure 2a, ANOVA; $F_{2, 138} = 1.501, p = 0.226$) and that they learned a lot from the course (Figure 2b; ANOVA; $F_{2, 139} = 1.412, p = 0.247$). Teaching style, independent study or stations based approach, did not have an effect on perception of course difficulty (Figure 2c, ANOVA; $F_{2, 135} = 0.626, p = 0.536$).

**Table 4. Study participants by year and teaching method**

<table>
<thead>
<tr>
<th>Year</th>
<th>Teaching Approach</th>
<th># respondents</th>
<th>% respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Independent study</td>
<td>43</td>
<td>64</td>
</tr>
<tr>
<td>2015</td>
<td>Station-Based Approach</td>
<td>48</td>
<td>69</td>
</tr>
<tr>
<td>2016</td>
<td>Station-Based Approach</td>
<td>75</td>
<td>93</td>
</tr>
</tbody>
</table>

"Material covered is important for my career"

(1 = strongly disagree → 5 = strongly agree)

**Figure 2a.**

![Figure 2a](image)

"I learned a lot..."

(1 = strongly disagree → 5 = strongly agree)

**Figure 2b.**

![Figure 2b](image)

"How challenging did you find the material?"

(1 = not challenging → 5 = very challenging)

**Figure 2c.**

![Figure 2c](image)
However, students taught using the SBA method reported significantly more interest and engagement with the material compared to students in the independent study cohort (Figure 3c; LSD; 2014 vs. 2015 p=0.015; 2014 vs. 2016 p=0.029). No significant differences were found between the two years where SBA was used (Figure 3c; LSD; p=0.509). Ability to apply and integrate learned material differed between the cohorts as well (ANOVA; F2, 138=4.467, p=0.013). Students taught with the SBA method (years 2015 and 2016) felt more confident that they can apply learned material, compared to the students taught using the independent study method (year 2014) (Figure 3c, LSD; 2014 vs. 2015 p=0.004; 2014 vs. 2016 p=0.038; 2015 vs. 2016 p=0.217). Furthermore, students taught using the SBA method reported feeling much more comfortable asking questions (Figure 3d, ANOVA, F2, 136=6.074, p=0.003; LSD 2014 vs. 2015 p=0.042; 2014 vs. 2016 p=0.001; 2015 vs. 2016 p=0.365). Students taught using the stations method also felt that stations decreased their stress levels (Figure 3a). Since students in the independent study cohort (year 2014) were never taught with the SBA method, they were omitted from the analysis of this question and the respective figure (Figure 3a).

Figure 3. Effect of teaching methods on student engagement. A) Stations affected student perception of stress, B) made the lab more engaging, C) helped students integrate and apply course material, and D) made the lab experience more interactive. Different letters above the standard error bars represent statistically significant differences between the teaching methods (p < 0.05). The bars represent the average Likert scores of students who took the course in different years, using different teaching methods; 2014 (white bar – independent study), 2015 (grey bar – SBA), and 2016 (black bar – SBA).
Evaluation of TA role in the laboratory

Student perception of TAs’ positive impact on the classroom differed between the teaching methods (Figure 4). Differences were found in TAs overall helpfulness (ANOVA; $F_{2,133} = 0.01$, $p < 0.01$), their ability to facilitate learning (ANOVA; $F_{2,133} = 0.01$, and decrease stress (ANOVA; $F_{2,133} = 0.00$). Students taught with the SBA perceived the TAs to be more helpful (Figure 4a, LSD; 2014 vs. 2015 $p = 0.000$, 2014 vs. 2016 $p < 0.01$, 2015 vs. 2016 $p = 0.858$). They also felt that the TAs helped reduce the stress levels (Figure 4b, LSD; 2014 vs. 2015 $p = 0.005$, 2014 vs. 2016 $p = 0.000$, 2015 vs. 2016 $p = 0.812$), and facilitated learning significantly more compared to the students taught using the independent study method (Figure 4c, LSD; 2014 vs. 2015 $p < 0.01$, 2014 vs. 2016 $p < 0.01$, 2015 vs. 2016 $p = 0.976$).

Discussion

Based on the results of our survey, as well as anecdotal evidence from informal conversations with students and teaching assistants, the SBA method makes the material more engaging, interactive, and also less intimidating for students with diverse science background (Figure 3). While all students, those in the independent study cohort and in the SBA method, felt that they learned a lot in the course and all found the material challenging (Figure 2), students in the SBA method felt much more positive about their overall lab experience (Figure 3a-d). Students in the SBA method felt that the stations made their learning experience less stressful (Figure 3a).

Even though students in the SBA did not learn the material independently as the 2014 cohort did, they had opportunities to study on their own. During the first lab of the semester, students study on their own and learn to use the lab resources following a very brief introduction by the instructor. The stations approach does not officially start until the second lab. Throughout the semester, students also had other opportunities to work independently. So even though these brief exposures to independent study do not directly compare to the experience of the independent study cohort, the SBA students still have a measure of comparison allowing them to compare the two learning methods.

Whelan et al. (2016) suggested that students believe that the independent learning style does not facilitate learning as efficiently as the facilitated active learning approach. Another study that assessed student perceptions on small group learning indicated that students have more favorable attitudes toward material as a result of small group learning (Springer et al. 1999). The station-based approach improves students’ perception of their ability to apply and integrate the material.

Ten-Cate and Durning (2007) found that the educational environment or learning climate appears to be important for optimizing learning. Additionally, Lockspeiser et al. (2008) found that peer-assisted learning helped with connecting

Figure 4. Effects of TAs on student perceptions of the course. Different letters above the standard error bars represent statistically significant differences between the teaching methods ($p < 0.05$). The bars represent the average Likert scores of students who took the course in different years, using different teaching methods; 2014 (white bar – independent study), 2015 (grey bar – SBA), and 2016 (black bar – SBA).
various concepts taught in the course and facilitated student organization of the information. A Station-based approach allows students to feel more comfortable asking questions. Whelan et al. (2016) indicated that students that experienced an independent learning environment expressed that their greatest concern was lack of timely and competent response to questions. Also, students that were taught with facilitated active learning were significantly more likely to report that their questions and confusion were addressed in a timely manner. Furthermore, small groups enabled students to ask questions and solve problems to further understand the concepts and that there was more effective communication between students and teachers (Lama et al. 2015).

One of the limitations of our study is that we were unable to quantitatively assess whether the different teaching methods affect retention and application of the course material. However, we know from other studies that positive perceptions of teaching methods have been shown to enhance student perceived ability to learn (Thomas et al. 2011). There is also evidence that occupational therapy students show a significant improvement in their ability to remember and explain anatomical material when using station-based methods and having student TAs (Thomas et al. 2011). Notwithstanding, for future studies, it would be important to assess the effectiveness of this method, not only on building student comfort and confidence, but also on student ability to understand and retain the Anatomy and Physiology concepts.

Similarly, teaching assistants helped reduce student stress and increase overall comfort in the course (Figure 4). These findings are in accordance with Whelan et al. who showed that students taught with an independent learning method perceived to meet less of the course objectives and to be less successful in learning than the students who were taught with facilitated active learning with tutors. Further, while the effects of facilitated active learning were highly variable depending on teaching style of tutor, the students taught with this approach were still significantly more likely to report that laboratory tutors facilitated their learning (Whelan et al. 2016).

While the SBA method is an effective pedagogical method to engage students, it does have some drawbacks. One such drawback is that the number of TAs limits the number of interactive stations in a given laboratory. However, even in a class of 18 students, it is possible to develop interactive stations with one TA and the professor (Table 2). It is not essential that an instructor oversee every minute of the students' time. It is possible to have two interactive stations and then stations where students review material independently or perform carefully structured activities that reinforce material covered at other stations. Furthermore, even in the absence of TAs, stations can be developed allowing groups of students to move from one activity to the next using POGIL (Process Oriented Guided Inquiry Learning) or other forms of collaborative group work. In the case where TAs are not available, the instructor can choose to hold one station or float between stations as students work through the material.

One of the great advantages of the SBA teaching method is the advanced anatomy training one can provide to motivated students seeking to learn Anatomy and Physiology beyond the two-semester course sequence. At Elizabethtown College, Human Anatomy and Physiology is the only course students have an opportunity to take to learn about human anatomy and physiology. We do not offer an advanced anatomy or physiology course. By giving motivated students an opportunity to work as TAs in the course, we are effectively giving the students a chance to improve their working understanding of Anatomy and Physiology by teaching it to others. Through regular TA meetings where TAs review relevant content and discuss effective pedagogical techniques, TAs often learn anatomy in greater depth. During our TA meetings we have had multiple discussions with TAs as they share their experience in upper level classes such as kinesiology, internships at physical therapy clinics, and various occupational therapy fieldwork assignments. These discussions are often engaging and result in regular improvements to content delivery, incorporating useful mnemonics, activities such as physical exercises, and examples into the course content.

The presence of actively engaged TAs in the classroom also significantly improves class dynamics. TAs facilitate communication between students and the instructor and help decrease student stress (Figure 4). According to Ten-Cate and Durning (2007), a teacher with a semantic network that more closely resembles that of the learner, like a near-peer, understands learning needs more easily and can offer help more efficiently. Since near pears are potentially seen as less threatening by learners and often have a rich understanding of the stresses of the school curriculum (Ten-Cate and Durning 2007), TAs can easily identify with students in the class and offer support through tutoring, open-labs, and advice (Ten-Cate and Durning 2007, Lockspeiser et al. 2008). Thus, station-based teaching allows TAs to have a positive role in the course by ultimately increasing overall student comfort and engagement in the course.

Conclusions
The SBA approach is flexible, and easy to adapt to topics of varying difficulty and different audiences. This method is also easy to implement using limited resources. The SBA allows the instructor to quickly identify and correct misconceptions because material is presented in discrete chunks, which is also less overwhelming for the students.

Using stations in the human anatomy and physiology lab can be an effective method to engage students and reduce stress. By incorporating teaching assistants in the laboratory, and allowing them to actively participate in the course design...
through teaching, the students taking the course as well as the teaching assistants benefit. The students in the course benefit by gaining increased access to the educator and a better support system to help them navigate the complex world of anatomy and physiology. The teaching assistants benefit through increased exposure to anatomy, teaching experience, and ultimately, a better preparation for board exams and graduate schools.

Finally, using stations, allows the sometimes monotonous review of structures to become interesting and interactive. Stations allow the instructor to arrange course content in a way that would be most applicable to their unique student audience and to develop activities that would engage them. Because stations are inherently modular, it is possible to easily modify and adjust lab activities to adjust for student/instructor interests, needs, and changes in learning outcomes.

Acknowledgements
The SBA method would not exist without the never-ending support and inspiration from Mark Nielsen and the opportunity to observe his TAs in the anatomy labs at University of Utah. We would also like to acknowledge the tireless efforts of the TAs at Elizabethtown College who have worked with us on developing and refining teaching stations throughout the years, faculty who have given us constructive criticism, and students that were always willing to try new ways of learning and give us objective and honest critiques. Funding from Elizabethtown College has allowed us to attend the 2017 conference and share our work.

About the Authors
Anya Goldina is an assistant professor of biology at Elizabethtown College. She teaches introductory biology courses, Human Anatomy and Physiology courses. Dr. Goldina received her PhD in Behavioral Endocrinology from Florida International University. Her broad research interests include animal behavior, endocrinology, and neuroscience.

Danielle Barattini is a master’s degree candidate in the Occupational Therapy program at Elizabethtown College. Danielle has been a teaching assistant for the Human Anatomy and Physiology course since 2015. In addition to teaching labs, Danielle has helped develop and implement the SBA method. Danielle is conducting research related to Anatomy and Physiology and the Occupational Therapy profession for her master’s thesis.

Literature cited


Textbook cited

“It started because of a snow day!” Making Online Videos as Customized Learning Tools

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Abstract
Instructors struggle with the amount of information they are expected to teach in the limited number of hours that are available in undergraduate human anatomy and physiology laboratories and students struggle with how to learn the terminology. When a snowstorm closed our campus, labs were cancelled for five of our fourteen lab sections. The graduate teaching assistants (GTAs) decided to make an online video using our models, presenting the terms for the week. Students who missed labs due to campus closure would be able to watch it in lieu of attending lab and keep up with those whose labs had not been canceled. The video received such positive feedback from students that the next semester, the GTAs produced the “Vanessa Videos” every week and posted them online for every lab section to utilize. The videos provide additional instruction outside of regular laboratory hours so that students can practice anatomy terms whenever it is convenient for them. doi: 10.21692/haps.2018.008

Keywords: use of technology, customized teaching, flipped learning

Introduction
In the first article in this series, we discussed the experience I had when I began teaching human anatomy and physiology at my new university. I met with my graduate student teaching assistants (GTAs) before the semester to ask their opinions on how to improve the lectures and labs (Rudolph and Schwabe 2017). The three GTAs I met with had extensive learning and teaching experience obtained from taking multiple anatomy and physiology courses, teaching many undergraduate laboratories, and working in biology research labs.

One of the GTAs suggested that we make short videos each week covering all the terms for the week, using the actual models we use in lab. The process of how the videos came to be is described in this article. A teacher’s guide is included to assist others who are interested in making their own videos.

How it All Began
It was a teaching tool born out of adversity. A lab practical was a week away and the University of Northern Colorado Greeley campus was closed because of snow. Students at the beginning of the week had been able to attend lab but many students had missed lab due to the campus closure.

The graduate teaching assistants put together a video to make the laboratory content available to those students whose labs had been canceled. The video was recorded and posted online, and the link was made available to all anatomy and physiology students. The video featured Vanessa, one of the GTAs, identifying all the bones of the skeletal system. She used the same lab models that would be used for the practical. Two weeks later, after the practical, we received feedback from students indicating that even those who had attended the lab the week of the snow closure used the video as a study tool for the practical.

Anatomy and physiology laboratory is a unique lab experience that relies heavily on the student’s ability to memorize terms and apply them to physical models. With the feedback we received from students, the idea occurred to us that more videos could be made for students to access the laboratory information outside of classroom hours when the models are otherwise inaccessible.

Revisiting and Mastering: Videos as an Additional Teaching/Learning Tool
The following school year we decided to record videos for the lab portion of the anatomy and physiology course. Over the course of the semester, GTAs Vanessa and Anna developed a flow and methodology for filming and posting videos through trial and error. Their method ultimately resulted in the ability to produce the best quality videos in the least amount of time.

The best method was recording the videos on a computer, so the computer could be turned towards the presenter and the screen could be adjusted for best visual angle and proximity to the presenter. Depending on how long the video was, it took an average of ten to fifteen minutes to reformat the videos for YouTube and then twenty minutes to upload it onto YouTube.

continued on next page
Anna used the iMovie application on her MacBook to record videos on her laptop. This hands-free approach allowed her to act as an off-screen assistant who could hand models to Vanessa as necessary.

**Decisions: How long should I talk?**
Vanessa and Anna decided to break up the terms list into mentally accessible chunks to avoid excessive video length that might prove to be unwieldy for students. Research supports optimal online mini-lecture video lengths of 15 minutes or less (Berg, Brand, Grant, and Zimmerman 2014). Ultimately, our videos ranged from 10 to 25 minutes once the process was optimized.

**Additional Benefits: A review/learning tool for new GTAs**
The videos were intended for students, but with each semester of anatomy and physiology new GTAs, several of whom have never taken an anatomy course, are directed to the videos as part of their preparation to teach lab. Prior to the availability of the videos for GTA training, it could take up to two hours of meetings per week to train a lab instructor. After the videos were implemented, an unpublished study found that 100% of the new GTAs and 25% of the experienced GTAs reported watching the videos as part of their preparation for labs.

**A Snow Day Left More Than Snow Behind**
Recording videos of materials to be covered in the laboratory section of an anatomy and physiology course requires time, knowledge, and care. However, the result is a long-lasting tool that allows students and GTAs, novice and experienced alike, to tailor their learning experience to the time frame that best suits them. The following Teacher’s Guide explains how we made the videos with some tips to help readers learn from our mistakes. Appendix A includes a list of our videos by topic and a link to those included in the first lab of them as examples.

**Teacher’s guide**

**Target audience:** High school through college level human anatomy classes. This exercise could be used with any lab where observation of detail and memorization of categories is the objective.

**Learning outcomes:**
Students should be able to identify and label the terminology assigned for a particular week on the models.

**HAPS Fundamental Content and Process Goals 1 and 2:**
1. Develop a vocabulary of appropriate terminology to effectively communicate information related to anatomy and physiology.
2. Recognize the anatomical structures and explain the physiological functions of body systems.

**Prior knowledge required:** Students need to know how to access files on the Learning Management System (LMS). Instructors need to know how to work a video camera and how to edit and upload the video to YouTube.

**Time required:** The instructor should allot three to four hours to allow for proper setup of the materials to be used, including diagrams that might be required on a whiteboard or a piece of paper. While this might seem like a lot of setup time, keep in mind that the videos, if well done and clear, will be used in several semesters and are well worth the initial time investment. Videos ideally should not exceed 15-20 minutes. If the required materials exceed 15-20 minutes of video time, the instructor should break up the material into multiple videos.

**Guidelines for classroom implementation**
Make students aware of where the videos can be accessed. The videos are not required material and should not replace lab time. They are to be viewed at the leisure of the student when it is convenient for them. Make the videos available the weekend before the associated lab is to take place. This allows students to be exposed to the materials prior to lab. We now have a document with the video links that is part of the lab orientation packet students receive on the first day of class. We remind them at multiple points throughout the semester that the videos are available and should be used as part of the regular study materials.

**Guidelines for design**
Instructors must have a clear set of terms or ideas to convey for the video that can be demonstrated in a way that directly correlates with how the student will be tested. For example, at the University of Northern Colorado students are tested in BIO 245 on a specific set of terms with the models that they have used throughout the semester. The videos include identification of structures and terms on the models that will be used for the practical. This material should be presented in an order that makes sense to the instructor.

The instructor may wish to include mnemonics or tips to recall vocabulary and the function or location of each term as it is pointed out on the model. For example “The stapes bone in the ear looks like a staple, or stirrup.” If the student must recall the function of the structure being identified be sure to explain its function clearly with a demonstration as necessary. For example, “The *biceps brachii* can be found on the anterior portion of the brachial region (point on model and on one’s own arm). The *biceps brachii* aids in flexion at the elbow (flex your own arm to demonstrate this).”

continued on next page
The UNC anatomy lab does not have a model for the sliding filament theory. As a result, the videos for this topic include diagrams and drawings on a white board. The diagrams are accompanied by a detailed explanation of the physiological process. Although we have no sliding filament model, the students must be able to demonstrate their knowledge of the sliding filament theory on the test. Demonstrating this process using a diagram helps them learn this complex theory.

The instructor who appears in the video must speak clearly, be emphatic, use eye contact with the camera to engage listeners, and be sure that all gestures and parts of the model are in-frame. The instructor should repeat the required words more than once. If the word has a strange spelling the instructor can choose to spell the term out loud and repeat that term.

**Instructor observations**

It is useful to have a second person available during the making of the videos to hand off models as necessary and to keep the instructor constantly in the frame. Attempting to film one’s self requires resetting the camera as the instructor moves and can cause awkward breaks in the video that unnecessarily increases the time it take to make the video. Having the models ready and someone to hand them to the instructor is key to a smooth presentation and keeps the presentation space from being cluttered.

It is helpful to students to clarify during lab time how terms will be indicated on the exam. For example, we use colored dot stickers directly on the models in a central area of the required structure. Since this is how we conduct our exams lab, we demonstrate this in the videos as well, being sure to point out all areas of the structure that are still within the scope of the term. For example, the required information might be that the inner ear includes the cochlea and the vestibule. This could be addressed in a question format, such as “The cochlea is found in which portion of the ear?” Alternatively, it could be addressed in a visual format by placing a dot on the area followed by a question about which portion of the ear is being indicated, such as “Which portion of the ear is indicated by the red dot?”

**Conclusion**

Videos can be a useful learning and teaching aid for students and instructors. It is not always possible to spend as much time with each student as students may want or need, so videos are an excellent bonus resource. Videos provide extra study time and a means to take the lab models (and a teaching assistant!) home to study independently. That is how the “Vanessa Videos” evolved from a snowy day in January!

The third article of this series will present data from surveys conducted in our labs in the spring 2018 semester. These surveys provide valuable information about how students perceive the effectiveness of changes we have made to the labs. We will look for correlations between grades and learning opportunities the students are participating in. Stay tuned!

**About the Authors**

Heather Rudolph is a postdoc who is passionate about teaching Anatomy and Physiology. She draws from both active and applied learning techniques in order to connect the formal classroom environment to real life experiences.

Anna Schwabe is a biology education doctoral candidate and certified scientific botanical illustrator. Her teaching expertise lies in maximizing student learning while fostering a teaching environment conducive to novice student instructors in Anatomy and Physiology labs.

Vanessa Johnson is a Master’s candidate who specializes in neurobiology and has developed an affection for anatomy and physiology education. She aims to transfer her own passion for biology to her students.

All authors contributed equally to this study.

**Literature cited:**


Appendix A

Lab 1
Regions of the body ................. https://youtu.be/60uQTLg_TY8
Body Movements ..................... https://youtu.be/FJe0U6GnlD8
Planes ..................................... https://youtu.be/zqr3xeTie0w
Body Orientation ...................... https://youtu.be/Upj3ewc1s5s
Body Cavities .......................... https://youtu.be/sCcBPrZwzTk
Microscope ............................. https://youtu.be/GFFNAKTdqCI
The Cell .................................. https://youtu.be/yIWeo5vxFKg

Lab 2
Connective Tissue Flowchart
Tissue Slides: Part 1
Tissue Slides: Part 2
Integument

Lab 3 and 4
Bone Microscopy
Axial and Appendicular Skeleton

Lab 5 and 6
Excitation Contraction Coupling Video
Muscle cell
Sliding Filament Theory Part 1
Sliding Filament Theory Part 2
Muscles of the Head and Neck
Muscles of the torso
Muscles of the upper limb
Muscles of the lower limb

Lab 7
Nervous Tissue
Spinal Cord Stuff
Spinal Cord
BRAINS!!!!
Cranial Nerves
Eyeball video
Ear Video
Olfaction and Gustation

Lab 8
Heart and Pulse
Heart Parts

Lab 9
Arteries
Blood Typing
Blood
Blood Vessels

Lab 10
Lower Digestive
Upper Digestive
Urinary and Kidneys

Lab 11
Respiration
Lung Volumes
Reproduction: Female
Reproduction: Male
Modeling Antibody-Epitope Interactions with 3D Printed Kits in Large or Small Lecture Courses

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Abstract
We used 3D printing to manufacture models that allow students to explore antibody-epitope interactions. One of the more difficult concepts for students in general microbiology and immunology courses is visualizing the interactions surrounding antibodies and the multiple epitopes found on antigens. We designed and printed antibodies that recognize different epitopes on the same viral antigen. Students can match different heavy chains and light chains creating 4 possible antigen-binding regions and then attempt to determine if and where on 3 possible viral antigens the antibody would bind. In this article we describe using 3D printing to create kits that can be used to demonstrate difficult concepts to students. The process used to develop these kits will be described as well as how the kits are used in large lecture (up to 150 students) flipped classes to augment student learning. This 3D model is available free for printing at https://www.thingiverse.com/thing:508595. doi: 10.21692/haps.2018.009

Key words: modeling, flipped classroom, team-based learning, active learning, 3D printing

Procedure
Modeling software
The kits were designed by a collaborative pair of honors students as an honors thesis project. One of the students was from Microbiology (Steven Denham) and one was from Computer Science (Dana Shatila). We searched for an open-source 3D modeling program that fit the following specific criteria:
1. An intuitive interface suitable for beginners.
2. Functions to create basic shapes and group them together (for the simple “Y” shape of an antibody or a plausible representation of a virus)
3) Tools that would allow us to make an impression of an object in a second object. In this case, the binding site would be the impression and the epitope the original object).

We modeled our antibodies and viruses in Tinkercad (https://tinkercad.com/). The in-browser-operated program utilizes two basic functions. The first function is shape creation. Users are initially limited to the shapes Tinkercad has to offer, or those that they can import. The second function is the ability to group shapes in order to create more intricate designs. When grouping, a shape may be designated as a “hole” or a “solid”. If overlapping solids are grouped, they will combine to form one shape. If an overlapping hole and solid are grouped, the hole will be subtracted from the new shape, leaving an imprint of its former self on the solid. We used this function to model our antibodies. We pressed antibody cylinder “solids” onto viral antigen “holes” and grouped them, leaving a perfect binding site impression in the antibody. Basic shapes were also arranged and grouped to design a cartoon version of Influenza A virus, which we eventually chose to be our model.

Design
Our complete model consisted of the following three distinct parts:
1. The virus (or virus cross-section).
2. An antibody specific for a distinct viral epitope.
3. A second antibody specific for another epitope from the same viral antigen.

We modeled our antibodies and viruses in Tinkercad (https://tinkercad.com/). The in-browser-operated program utilizes two basic functions. The first function is shape creation. Users are initially limited to the shapes Tinkercad has to offer, or those that they can import. The second function is the ability to group shapes in order to create more intricate designs. When grouping, a shape may be designated as a “hole” or a “solid”. If overlapping solids are grouped, they will combine to form one shape. If an overlapping hole and solid are grouped, the hole will be subtracted from the new shape, leaving an imprint of its former self on the solid. We used this function to model our antibodies. We pressed antibody cylinder “solids” onto viral antigen “holes” and grouped them, leaving a perfect binding site impression in the antibody. Basic shapes were also arranged and grouped to design a cartoon version of Influenza A virus, which we eventually chose to be our model.

The antibody heavy and light chains were printed separately and combined after inserting magnets at the interface (Figure 1). We considered using accurate viral models reconstructed from X-ray crystallography and Cryo-EM models on the Vipr database to STL (STereoLithography) files for printing (Carrillo-Tripp et al. 2009). These models are extremely accurate representations of viral capsids and can serve as excellent teaching tools. However, for the purpose of modeling antibody-epitope interactions, accurate viral prints proved too ambiguous for students (Figures 2). Surface features were not prominent enough for a clear and practical distinction between potential antibody binding sites.

continued on next page
In order to reduce ambiguity concerning potential viral epitopes, we chose to model our own representation of a virus (Figure 1). We used Influenza A based on its prominent antigens hemagglutinin (HA) and neuraminidase (NA). HA is a glycoprotein that binds sialic acid on host cell membranes and mediates viral entry. NA is an enzyme that cleaves sialic acid when progeny virions bud from host cells, allowing them to spread to new cells. Both HA and NA are essential for efficient Influenza A replication. They are also highly immunogenic and form the basis for influenza vaccine development, which provides a translational component to the exercise. We did not replicate actual viral structure in our model, but rather intended to create a clear representation of the virus and its antigens. The result is more of a cartoon representation Influenza A that can be printed as a cross section or as a complete virus. HA is represented as a spike with three spheres attached and NA is a cylinder with a bowl at the end (Figures 1). We designed two antibodies that would both bind epitopes of HA. One antibody binds to M2 ion channels the HA spheres and the other binds to the HA spike (Figure 1). HA and NA were modeled at an accurate ratio of 4:1 (HA:NA) on the virus cross-section (Kilbourne et al., 2013). M2 ion channels (oval holes), which maintain pH across the viral envelope during endocytosis into the cell, were added to the viral surface for additional detail, but are not intended to be bound by our antibodies (Figure 1). The antibodies and virus are not modeled to scale. For accurate scaling, antibody size would need to be reduced by 75%. Antibodies are about 15-20nm (Alzari et al. 1988) in length, while Influenza A virus particles are 80-120nm in diameter (Norkin 2009).

Printers

We received valuable consultation and support from Colorado State University’s Idea2Product (I2P) lab, which supports a wide range of creative projects by providing CSU affiliates and the local community with access to their 3D printing services. We printed our models (STL file format) from Afinia© printers using polylactic acid plastic. Multiple printer types and materials are available with varying costs and suitability for projects. Multiple printers may need to be explored to find the best printer and material for a specific print job.

Before In-Class Activity

Students are asked to watch a mini-lecture video on the immune system and antibodies at home before coming to the flipped class period. The mini-lecture video is 13 minutes long. The video was created by the instructor using lecture capture software and then posted to the University’s learning management system. To ensure that students watch the video, they are required to take a five-point, five-question, online pre-quiz before coming to class on the day of the activity.

---

**Figure 1:** 3D Printed Model Contents. Influenza A cross-section and antibodies. Influenza virus with hemagglutinin (HA), neuraminidase (NA) and M2 ion channels (M2). Refrigerator 2mm thick, 6 mm diameter magnets are glued (any craft glue) into the circular indents so that the light (LC) and heavy (HC) chains snap together. Note: be sure to glue magnets in such that they attract and do not repel one another.

**Figure 2.** Adenovirus 3D Model. Adenovirus reconstructed from X-ray crystallography and Cryo-EM models on the Vipr database to STL (STereoLithography) files for printing in Tinkercad.
25-Minute In-Class Activity

Learning outcomes for this activity in a flipped classroom

After this activity, students should be able to:

1. Describe how antigens and epitopes are related.
2. Explain why some antibodies that do not bind to epitopes are produced.
3. Discuss which regions on the heavy and light chains come together to bind to specific epitopes.
4. Identify the region on the antibody that determines its class or isotype.

Students are given the following:

1. A student directions handout (Appendix 1).
2. A kit containing two heavy chains (disulfide bonded together), one yellow and one red; and four light chains, two blue and two green.

To maximize time, the instructor gives the students brief directions while undergraduate learning assistants (ULAs) hand out the materials (five minutes).

Once all the materials are handed out, the instructor spends about 15 minutes going through a worksheet (Appendix 1) and an ungraded PowerPoint clicker quiz (Appendix 2) in which students are asked to predict the epitope binding of given pairs of heavy and light chains.

In total, they will work with four different combinations, two of which will bind an epitope on the same antigen on the virus, and two of which will not have specificity for the virus. This allows students to understand that not all antibodies will be specific for an epitope on an infecting microbe.

The remaining few minutes of activity are used to collect the kits. The second half of the 50-minute class is devoted to lecturing about vaccination.

Discussion

On average over four semesters 91% of students were able to correctly identify the epitope to which an antibody would bind using these kits (Figure 3). Interestingly, when the combination of heavy and light chains did not bind to any epitopes on the virus only 63% of students answered that the antibodies were not specific for any epitope. This could indicate either that students do not understand that not all of the randomly created antibodies will have specificity for a given infection, or they are not confident enough to answer “none of these”. However, after seeing the first antibody that was not specific for any epitopes and discussing how this was possible, when they were given a second antibody that was not specific for the virus 91% answered “none of these”, and 96% correctly identified the epitope binding site of the second antibody that had viral specificity (Figure 3).

3D printing is a powerful tool and will assume an influential role in years to come. Our project provided an example of how it can be used to create a valuable teaching kit. Though the basic concept is the same for most all printers, the material capabilities and precision is extremely varied. Before embarking on a 3D printing project, it is essential to research and choose the right printer and modeling software for the job.

Our efforts yielded cartoon antibody and virus models, which interact in order to demonstrate some key concepts in antibody-epitope binding. Though designed in order to show how a single antigen may have multiple epitopes, students can also explore concepts such as agglutination, crosslinking, neutralization and isotypes (with the addition of antibodies with longer heavy chains to the instructor’s kit).

Many students excel at various types of learning, and having a physical model in front of them can be a beneficial addition to textbooks and lectures.

About the Authors

Dr. Erica Suchman, professor and Dr. Jennifer McLean, assistant professor Department of Microbiology, Immunology and Pathology, worked with honor students Steven T Denham (microbiology) and Dana Shatila (Computer Science) in collaboration with Dr David Prowel Assistant Research Professor Department of Mechanical Engineering to develop 3D printed models for teaching.
Supplemental Materials:
Appendix 1: Student Directions Handout worksheet to be filled out during class, and key

Antibody-Antigen-Epitope
3D Model Flipped Classroom Activity

Before you begin...
1. Label the light chains of this antibody with the letter “L.”
2. Label the heavy chains of this antibody with the letter “H.”
3. Draw rectangles around the variable regions on this antibody.
4. Circle the constant region(s) on this antibody.
5. Draw an arrow to the region that may bind to a specific epitope.
6. Draw a star on the region of this antibody that determines its isotype/class.

7. What is/are the antigen(s) in this picture?
8. Where are the potential epitopes?

After this activity, you should be able to:
1. Describe how antigens and epitopes are related.
2. Explain why some antibodies get made that do not bind to any epitopes.
3. Discuss which regions on the heavy and light chains come together to bind to a specific epitope.
4. Identify the region on the antibody that determines its class or isotype.
Appendix 2: In class clicker quiz PowerPoint

What epitope does the combination of Heavy chain yellow and light chain blue bind to?

A. A
B. B
C. C
D. D
E. None of these

What epitope does the combination of Heavy chain yellow and light chain green bind to?

A. A
B. B
C. C
D. D
E. None of these

What epitope does the combination of Heavy chain Red and light chain blue bind to?

A. A
B. B
C. C
D. D
E. None of these

What epitope does the combination of Heavy chain Red and light chain green bind to?

A. A
B. B
C. C
D. D
E. None of these

Heavy chain Yellow and light chain blue binds epitope C

Heavy chain Red and light chain Green bind B

continued on next page
Modeling Antibody-Epitope Interactions with 3D Printed Kits in Large or Small Lecture Courses

Literature cited


Software:
Tinkercad: https://tinkercad.com/
Regional Approach to Musculoskeletal System Instruction May Enhance Student Performance

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Abstract
The purpose of this study was to compare instruction effectiveness between a regional approach and a systems approach in teaching the musculoskeletal system to sophomore-level anatomy and physiology students. Exam grades from two consecutive fall semesters were compared. Laboratory materials for the second and third exams were presented using a systems approach first, followed by using a regional approach. This order was used with students (n=139) in the first year of the study. In the second year of the study, the order of presentation was reversed for students (n=144) so that the regional approach was used first, followed by a systems approach. There was no significant difference in the test scores for the first exam between the years, suggesting that there was no difference in overall student ability between years. The overall class average on the third exam was significantly higher (p<0.05), both within year and between years, when the material was presented in a regional approach first. However, correlation analysis did not suggest an increase in individual student performance. Results suggest that spaced repetition and testing of the course material may enhance learning. doi: 10.21692/haps.2018.010

Key words: system-based approach, regional-based approach, musculoskeletal, instruction

Introduction
One of the changes that resulted from the Institute of Medicine's recommendation for medical education reform in 2003 (Greiner and Knebel 2003) was a more system-based curriculum (Bilderback et al. 2008). Arslan (2014) suggests that a system-based anatomy curriculum has many advantages, in particular the reintroduction of structures at numerous times throughout the academic year. For example, the anatomy of the musculoskeletal system is reintroduced in discussions of cardiovascular and respiratory physiology, which in turn leads to increased student performance in the areas of pathology, clinical medicine, and clinical reasoning. Syed et al. (2014) observed that a systems-based approach for physician assistant students led to strong performance on examinations.

Undergraduate anatomy and physiology courses are often taught using a system-based approach, but like many introductory science classes they have a relatively high rate of students who do not achieve success. While there are few published articles to date specifically on this topic, attrition rates of approximately 50% in undergraduate anatomy and physiology courses have been reported (Hopp 2009, Hopper 2011). The purpose of this study was to determine if a regional-based approach to the musculoskeletal system in the laboratory portion of the sophomore-level anatomy and physiology course would improve student performance.

Methods
Approval for this study was obtained from the Institutional Review Board of the University of Nebraska at Kearney (IRB protocol #062716-1). Students in Biology 225, Anatomy and Physiology I, fall 2016 and fall 2017, were recruited to participate in the study. Biology 225 is the first course in a two-semester sequence and college-level chemistry is the required prerequisite. All students received an invitation to participate in the study and informed consent was obtained via email for the use of student laboratory exam scores and their final grade. Students who consented to participate in the study did nothing differently from other students in the class.

The laboratory portion of the course was divided into three, five-week sections. Each section included four weeks of laboratory activities followed by a laboratory practical exam. The first laboratory practical exam covered basic terminology and organization, movements through membranes, tissues, the integumentary system, basic microscopic and macroscopic anatomy of bones, and types of joints. The second laboratory exam covered the bones and bone features, joints, and muscles of the upper body, and the third laboratory exam covered the bones and bone features, joints, and muscles of the lower body. The laboratory was not dissection-based or cadaver-based; students used skeletons, isolated bones, models, manikins, and illustrations to learn the required structures and were tested using these same materials.

Laboratory exercises for laboratory exam one were identical for students in both years of the study. Laboratory exercises for laboratory exam two in the fall of 2016 were organized using a systems approach while laboratory exercises for laboratory exam three were organized using a regional approach. The order of presentation was reversed in the fall of 2017 in that laboratory exercises for laboratory exam two were organized...
using a regional approach and those for laboratory exam three were organized using a systems approach. Objectives for the first laboratory exercise in preparation for laboratory exam two each year are presented in Figures 1 and 2. Great care was taken to ensure that laboratory exam two and laboratory exam three covered approximately the same number of bones, bone features, joints, and muscles. Students were required to know the origin, insertion, and action(s) of muscles.

All other aspects of the course, including the content, number, and scheduling of lecture exams as well as the timing of fall break and Thanksgiving break relative to laboratory exams, were identical each year. Only the performances of students who consented to participate in the study and then earned a final grade of 70% or higher were included in data analysis. The rationale for this was that the last date of class attendance must be reported for all students who fail a class at my institution. The last date of attendance is important for financial aid considerations. Therefore, some students who have made a conscious decision to change programs of study may complete all aspects of the course so as to document attendance but not put much effort into preparing for exams following the withdraw deadline. The range of scores on the last laboratory exam in 2017, for example, was from 100% to 16%. Therefore, only students who achieved a satisfactory overall grade, suggesting they were putting meaningful effort into preparation, were included in the final data analysis.

Results of exams were analyzed within year using ANOVA and between years using a t-test. In both significance was ascribed for p<0.05. Correlation analysis was also performed on the results of the second and third exams within year.

### Results

A total of 139 students consented and qualified (earned a final grade of 70% or better) to participate in the study in the fall of 2016 and 144 students consented and qualified to participate in the study in the fall of 2017. There was no difference in student performance on exams one or two between years, but student performance on exam three was significantly higher in 2017 (Table I). Within years, student performance on exam one was significantly lowest both years, but student performance on exam three was significantly higher from student performance on both exams one and two only in 2017. Correlation analysis between student performance in the second and third exams demonstrates a moderate positive correlation each year (2016 r = 0.62; 2017 r = 0.65) but no meaningful difference between years.

### Discussion

The results of this study suggest that, while presenting the material in a regional approach did not have an immediate impact on student performance, students who were first presented with the material in a regional approach performed significantly better on the next exam than did those students who were presented with the material in a systems approach first. This observation is significant in two ways. First, student performance on laboratory exam one serves as a control in that the course materials were presented in identical fashion both years and there was no difference in student performance on that exam. The observation that student performance on exam one was significantly lowest both years suggests that the act of taking a practical exam allows students to learn how to better prepare to take subsequent practical exams. In addition, the final overall grades for the students were also not significantly different (2016 and 2017) in exam one and two between years using a two-tailed t-test. Significance was ascribed for p<0.05.

<table>
<thead>
<tr>
<th>Year</th>
<th>Exam 1</th>
<th>Exam 12</th>
<th>Exam 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016 (n = 139)</td>
<td>80.1 ± 10.1</td>
<td>82.8 ± 9.8*</td>
<td>83.8 ± 10.9*</td>
</tr>
<tr>
<td>2017 (n = 144)</td>
<td>81.2 ± 10.1</td>
<td>84.2 ± 9.3*</td>
<td>88.2 ± 8.9*#@</td>
</tr>
</tbody>
</table>

* significantly different from exam 1 within year
# significantly different from exam 2 within year
@ significantly different from same exam 2016

**Table 1.** Laboratory practical exam results (average percentage correct ± SD) for Anatomy and Physiology I students who earned a final grade of at least 70% in the course. Exams were identical both years, and material presented for exam 1 was identical both years. In 2016 students were presented with the material first in a systems approach (exam 2) and then a regional approach (exam 3). In 2017 students were presented with the material first in a regional approach (exam 2) and then a systems approach (exam 3). Data were analyzed within year using ANOVA and between years using a two-tailed t-test. Significance was ascribed for p<0.05.
Objectives common to both approaches:

Learning objectives – bones and bone features of the skull

1. Identify the following bones and features of the bones of the skull (number of each in parentheses):
   - ethmoid (1)
   - frontal (1)
   - lacrimal (2)
   - mandible (1) - coronoid process, mandibular condyle (condyloid process or head), mandibular foramen, mental foramen, ramus
   - maxillary (maxilla) (2)
   - nasal (2)
   - occipital (1) - foramen magnum, occipital condyle
   - palatine (2)
   - parietal (2)
   - sphenoid (1) – foramen ovale
   - temporal (2) – mandibular fossa, mastoid process, stylomastoid foramen, zygomatic process
   - vomer (1)
   - zygomatic (or malar) (2) - temporal process

2. Identify the following features of the clavicle: sternal (medial) end, acromial (lateral) end
3. Classify the above bones according to their shape: flat, irregular, long
4. Identify the following features of the skull: anterior and posterior fontanels (fetal and infant skull only), jugular foramen, zygomatic arch
5. Identify the hyoid bone

Objectives unique to systems approach:

Learning objectives – bones of the shoulder, arm, wrist, and hand

1. Scapula – glenoid cavity (fossa), infraspinous fossa, supraspinous fossa, subscapular fossa, lateral border, medial border, superior border
2. Humerus - (proximal) head (epiphysis), greater and lesser tubercles, intertubercular sulcus (groove), deltoid tuberosity, lateral and medial epicondyles, olecranon fossa, coronoid fossa
3. Radius - (proximal) head, radial tuberosity, styloid process
4. Ulna - coronoid process, (distal) head, radial notch, olecranon process, styloid process
5. Carpals - lunate, scaphoid (navicular), capitate, trapezoid (lesser multangular), trapezium (greater multangular), pisiform, triangular (triquetrum), hamate
6. Metacarpals - first, second, third, fourth, fifth
7. Phalanges - proximal, middle, distal

Learning objectives – bone shape

Classify the above bones by shape: flat, long, short

Objectives unique to the regional approach:

Learning objectives – joints of the skull

1. Identify the following examples of fibrous joints:
   - suture - cranial and facial bones
   - gomphosis - tooth fastened into mandible or maxilla
2. Explain the role of dense connective tissue in fibrous joints
3. Identify the following example of a synovial joint and list a specific type of movement possible:
   - "modified" hinge - temporal bone and mandible
4. Explain the role of hyaline cartilage in synovial joints
5. Identify if a joint is synarthrotic or diarthrotic
6. Identify the four sutures of the cranium: coronal, lambdoid (lambda or lambdoidal), sagittal, squamous (or squamosal)

Learning objectives – muscles of facial expression and head movement

1. Identify the following muscles, including their origin(s), insertion(s), and action(s):
   - buccinator
   - epicranius (also called occipitofrontalis)
   - masseter
   - orbicularis oculi
   - orbicularis oris
   - sternocleidomastoid
   - temporalis
   - zygomaticus major
   - zygomaticus minor

Figure 1. Learning objectives for the first week of laboratory in preparation for laboratory exam 2, which covered the musculoskeletal anatomy of the upper body.

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continued on next page
Examples of questions common to both approaches:

1. The _____ foramen is a feature of the skull because it cannot be viewed on any individual bone in isolation.
2. When classifying bones by shape, all bones of the face are _____.
3. The _____ of the temporal bone and the _____ of the zygomatic bone join together to form the _____.
4. A "catch-all" term for a prominent projection on a bone is a(n) _____.

Examples of questions unique to the systems approach:

1. A(n) _____ is a rounded process of a bone located at an articulation site. This feature of the humerus rests in a depression called the _____ of the scapula.
2. The spine of the scapula forms a large lateral projection called the _____.
3. The feature on the proximal end of the ulna that forms the “elbow” is the _____.
4. When classifying bones based on shape, all the bones of the wrist as classified as _____ bones.

Examples of questions unique to the regional approach:

1. The muscle that inserts on the coronoid process and ramus of the mandible and acts to elevate the mandible is the _____.
2. The mandibular fossa and mandibular condyle are covered with a thin layer of _____ cartilage. This forms the articular cartilage typical of synovial joints and helps to minimize friction.
3. Based on their anatomy, the sutures of the skull are a type of _____ joint. The two sutures that follow body planes are the _____ and _____ sutures. Based on their degree of movement, these joints are classified as _____.
4. The muscle located in the buccal region that originates on the maxilla and mandible is the _____.

Figure 2. Examples of questions from the students’ laboratory exercises for the first week of laboratory in preparation for laboratory exam 2, which covered the musculoskeletal anatomy of the upper body.
average 84.0 ± 7.7 percent; 2017 average 83.4 ± 7.0 percent). Therefore, the overall academic performance of students participating in the study each year was similar. Second, four of the five laboratory instructors were the same both years, and the laboratory exercises are organized in such a way that learning objectives are very clear. All laboratory instructors strive for consistency between lab sections so that a student with a conflict (travel for athletics, for example) can attend a different lab section and have an experience similar to what he or she would have in the regular lab section. In addition, grading instructions and criteria for exams were very clear so as to ensure consistency in grading across instructors. Therefore, the significant difference in performance observed on exam three in the fall of 2017, both within and between years, could potentially be due to the difference in how the material was presented. Unfortunately, correlation analysis did not lend much support to this conclusion. Efforts to minimize variables by keeping all aspects of the class identical other than presentation arrangement (systems or regional approach) may have contributed to this. That is, because laboratory activities were only rearranged and not tailored specifically to each approach, the potential impact of the regional approach on student learning was most likely compromised.

One limitation to the study is that not all students who completed the class were included in data analysis. A notation of the last date of class attendance is required for all students who fail a class at my institution, which encourages students to complete all aspects of the course. Students who have made a conscious decision to change programs of study, however, may not put much effort into preparing for exams following the drop deadline. The range of scores on the last laboratory exam 2017, for example, was 100% to 16%. Therefore, only students who achieved a satisfactory overall grade were included in the final data analysis.

Previous experience in an anatomy and/or physiology course has been shown to have a positive effect on adjustment to medical school (Miller et al. 2002). The organization of the musculoskeletal system into a regional approach rather than the examination of the bones, joints, and muscles separately is consistent with the approach suggested by Arslan (2014). It is hypothesized that prior experience with anatomy presented in a regional approach will not only improve performance in the sophomore level course but also ease the transition to professional school. In addition, the presentation using a regional approach is consistent with the concept of “spaced repetition,” in which subject matter is repeated and tested over a period of time (Cohen et al. 2013, Karpicke and Bauernschmidt 2011, Logan et al. 2011). The results of this study suggest that using the regional approach, which required students to think of bone features as muscle attachments weekly and incorporate those attachments into joint movements simultaneously, better incorporates spaced repetition and leads to increased learning when students are tested on similar concepts in the future.

About the Author
Janet Steele, PhD, is a Professor of Biology and Associate Dean for the College of Graduate Studies and Research at the University of Nebraska at Kearney. She has been teaching anatomy and physiology to sophomores for 25 years.

Literature cited
Student Perceived Difficulties in Learning Organ Systems in an Undergraduate Human Anatomy Course

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Abstract
Learning human anatomy may be a difficult task for students for a variety of reasons including the quantity of material in the course or discipline-specific factors such as understanding anatomical terminology or learning complex physiological processes. Additionally, students may find certain organ systems more challenging than others. While prior studies have assessed student perceptions of learning specific organ systems in a variety of settings, it is unknown what organ systems students in an undergraduate human anatomy course find most difficult to learn. The goals of this study were to determine what organ systems undergraduate human anatomy students find most and least challenging to learn and to determine the reasons why they feel as they do. The results of this study showed that students overwhelmingly found the peripheral nervous system to be the most difficult to learn because of complex structure-function relationships and their inability to visualize the system. Conversely, students thought that the cardiovascular and skeletal systems were the least challenging to learn because of prior exposure to them and ease of visualization. These findings allow for the development and alteration of instructional strategies to address the issues that students face when learning about difficult organ systems. doi: 10.21692/haps.2018.011

Key words: human anatomy, undergraduate education, student perceptions, assessment, organ systems

Introduction
Students may have difficulty learning the subject matter of the anatomical sciences. Reasons for this may include issues with motivation, course content, and the quantity of information. Bergman et al. (2013) surveyed medical students’ perceptions of a problem-based learning (PBL) curriculum and found that many students found anatomy boring and believed that it required self-discipline more than intellectual ability to learn the large quantity of information. However, students reported that when anatomy was taught in a clinical context it helped to increase student motivation and learning. At the college level, allied health students reported that discipline-specific factors, such as the need to learn muscle origins and insertions and the need to understand complex physiological processes like the cardiac cycle, were the most important reasons why undergraduate human anatomy and physiology courses are difficult (Sturges and Maurer 2013).

A survey of faculty members regarding the difficulty of learning human physiology found similar results in that faculty most commonly cited discipline-specific factors for why physiology is difficult to learn (Michael 2007). Students may perceive anatomy as purely an exercise in memorization, which may affect their attitude towards studying anatomy and lead to difficulties with the course (Miller et al. 2002). Undergraduate human anatomy students reported that the quantity of material presented in the course was what prevented them from learning anatomy successfully (Wright 2012). Due to these perceptions and other factors, undergraduate anatomy and physiology courses may have high drop out, failure, and withdrawal (DFW) rates (Harris et al. 2004, Sturges et al. 2016).

While these studies have demonstrated that students in general can perceive anatomy as difficult, students may find specific topics to be particularly difficult to learn for a myriad of reasons. If specific problem areas can be identified, then pedagogical tools can be developed to address them and improve student outcomes. Kramer and Soley (2002) surveyed second year medical students to determine what specific anatomical concepts were “problem topics.” The pelvis was listed as problematic by 39 percent of students, while 35 percent found neuroanatomy problematic and 30 percent listed the perineum as difficult. In a survey of first-year dental students, Parkin and Rutherford (1990) found that while students enjoyed studying neuroanatomy, they found it difficult to learn.

At the pre-health professional level, Higazi (2011) reported that students enrolled in an introductory college-level human anatomy and physiology course found that histology was the most difficult subject to learn. In response, interactive imaging exercises were designed to improve learning outcomes. Gopal et al. (2010) surveyed introductory anatomy and physiology students and instructors and the majority of both groups responded that the cardiovascular system was most difficult to learn or teach. To address this issue, the researchers developed interactive web-based tools to improve cardiovascular system continued on next page
instruction and found that students who used these tools significantly improved on summative laboratory assessments (Gopal et al. 2010).

While these findings suggest that students find certain anatomical topics more difficult than others, no studies to date have examined student perceived difficulties in pre-health professional human anatomy courses. This is an important subset of students to study since human anatomy is routinely taught at undergraduate institutions in the United States and student success in undergraduate anatomy has been linked to performance in medical school gross anatomy (Forester et al. 2002). The goals of this study were to determine what specific organ systems undergraduate human anatomy students found most and least difficult to learn and to determine why they held these perceptions. The results of this analysis can be used to design instructional tools or activities to address specific problem areas in teaching human anatomy at the undergraduate level.

Materials and Methods
Course and participant descriptions.
This study examined a high structure undergraduate human anatomy course taught in the ten-week quarter system at a large research-intensive university in the southwestern United States. As a high structure course, the course included pre-class textbook reading, graded online assignments, individual and group active learning in-class, and graded weekly review quizzes (Shaffer 2016). The course included three 50-minute lecture periods a week and three hours of laboratory a week for a total of 25 hours of lecture and 30 hours of laboratory. The lecture portion of this course was taught by one of the authors (JS) with a systems approach. The course included pre-class textbook readings and graded online assignments, in-class active learning, and graded online weekly review quizzes. Trained graduate student teaching assistants taught the laboratory portion of the course. Laboratory guides designed to facilitate student interactions with plastic anatomical models and animal dissections (sheep brain, heart, and kidney) were used. Cadavers were not used in this course. For more information on this course, please see (Shaffer 2016).

The textbook for the course was Human Anatomy (7/e) (Marieb et al. 2014), which guides students through learning human anatomy system by system. The systems were taught in the following order: tissues and histology, integumentary system, skeletal system, muscular system, nervous system (central, peripheral, and autonomic), cardiovascular system, lymphatic system, respiratory system, digestive system, urinary system, and reproductive systems. The endocrine and immune systems were not taught. Table 1 provides a summary of the order of organ systems, the number of lecture sessions devoted to each system, the number of laboratory sessions devoted to each system, and the number of terms or structures that students were required to know about each system.

Table 1. Order of organ systems taught in the course and approximate time devoted to each. The number of structures or terms that students were required to know about each organ system is also shown.

<table>
<thead>
<tr>
<th>Organ system</th>
<th>Number of lecture periods</th>
<th>Number of laboratory periods</th>
<th>Number of required terms or structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integumentary</td>
<td>1</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Skeletal</td>
<td>5</td>
<td>2</td>
<td>317</td>
</tr>
<tr>
<td>Muscular</td>
<td>2</td>
<td>1</td>
<td>102</td>
</tr>
<tr>
<td>Central nervous</td>
<td>2</td>
<td>0.5</td>
<td>153</td>
</tr>
<tr>
<td>Peripheral nervous</td>
<td>3</td>
<td>0.5</td>
<td>159</td>
</tr>
<tr>
<td>Autonomic nervous</td>
<td>1</td>
<td>0</td>
<td>59</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>1.75</td>
<td>0.75</td>
<td>138</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>0.25</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Respiratory</td>
<td>1</td>
<td>0.25</td>
<td>65</td>
</tr>
<tr>
<td>Digestive</td>
<td>1</td>
<td>0.33</td>
<td>92</td>
</tr>
<tr>
<td>Urinary</td>
<td>1</td>
<td>0.33</td>
<td>39</td>
</tr>
<tr>
<td>Male reproductive</td>
<td>0.5</td>
<td>0.165</td>
<td>28</td>
</tr>
<tr>
<td>Female reproductive</td>
<td>0.5</td>
<td>0.165</td>
<td>30</td>
</tr>
</tbody>
</table>

continued on next page
This study surveyed 255 students in two sections of this course: Winter 2016 (n = 127) and Spring 2016 (n = 128). Students enrolled in this course were majoring in biological sciences (65.6%), nursing sciences (16.0%), pharmaceutical sciences (10.9%), or other (7.4%). The majority of the students were female (70.3%) and Asian (71.5%). The remaining ethnic breakdown was 13.3% Caucasian, 12.9% Latin@, and 1.6% African-American. A passing grade of “C” or better in a human physiology lecture course was a pre-requisite for enrolling in the course. The course was an elective for all majors except nursing science.

Data collection
This study analyzed data obtained from 255 students in two sections of this course: Winter 2016 (n = 127) and Spring 2016 (n = 128). To be included in this study, students had to give their consent, complete all major summative assessments (lecture and laboratory practical exams), and complete an end-of-course survey. Overall, 78% of students (n = 198) met these requirements and thus were included in this study. The data collected from each course section were combined in this analysis as similar results were obtained for individual sections. The Institutional Review Board of the University of California, Irvine, approved this study (HS# 2013-9959).

Data in this study were collected from an identifiable survey given online during the last week of the course after the last day of instruction had occurred. The survey was open for several days and closed before the final exam in the course. Students were asked to evaluate many components of the course including their perceptions of learning the organ systems of the human body. Students were asked to choose from a drop-down list which organ system they felt was most difficult to learn and which organ system they felt was least challenging to learn. They were also asked to explain their choices through two open-ended questions; one for the most difficult organ system and one for the least challenging organ system. Students were given points equal to 0.3% of their course grade for completing the survey.

Data analysis and statistics
Two analyses were performed in this study:

1) To determine what organ systems students perceived as most / least difficult, students chose a single organ system as most difficult and a single organ system as least difficult on the end of course survey (Table 2). Responses for each organ system were counted and are reported as a percentage of the total number of responses. Data were analyzed using Microsoft Excel 2011 (Microsoft, Redmond, WA).

To determine why students perceived a given organ system as most / least difficult, students wrote comments in the end of the course survey explaining their reasoning for choosing an organ system as most / least difficult.

An iterative qualitative analysis of the written comments, similar to that performed in previous studies, was performed by two researchers (JS and RL) (Welsh 2012, Heiner et al. 2014, Sato et al. 2017). Initially, student comments from the Winter 2016 course section (n = 196 comments; 98 each for most and least difficult organ systems, respectively) were read and coded independently by the researchers. They then met to discuss the emergent themes and agreed upon an initial set of themes. After reviewing the same set of comments, the researchers met again to discuss whether the initial set of themes was viable and whether changes were necessary. At this time, the initial set of themes was revised and the researchers agreed upon a final set of nine themes (Table 3). They then coded the student comments from the Spring 2016 course section (n = 200 comments; 100 each for most and least difficult organ systems, respectively). The data from both course sections were then combined to yield a total of 198 comments describing the most difficult organ system with 425 applied themes and 198 comments describing the least difficult organ system with 301 applied themes.

Inter-rater reliability was determined at the conclusion of the coding process. As comments tended to have more than one theme applied, inter-rater reliability was characterized in terms of a complete match (all assigned themes matched between the researchers), a partial match (some, but not all themes matched between the researchers), and no match (no assigned themes matched between the researchers). The researchers had complete matches with 70% of the comments, partial matches with 24% of the comments, and no matches with 6% of the comments. Any conflicts in themes were discussed until a consensus was reached.
Table 2. Percentage of students reporting organ systems as most or least difficult. Organ systems are presented according to the order that they were taught in the course. Data are presented as a percentage of the study sample (n = 198).

<table>
<thead>
<tr>
<th>Organ system</th>
<th>Most difficult (%)</th>
<th>Least difficult (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integumentary</td>
<td>4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Skeletal</td>
<td>1.5</td>
<td>24.7</td>
</tr>
<tr>
<td>Muscular</td>
<td>13.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Central nervous</td>
<td>26.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Peripheral nervous</td>
<td>30.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Autonomic nervous</td>
<td>14.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>5.1</td>
<td>27.8</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Respiratory</td>
<td>0.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Digestive</td>
<td>2.0</td>
<td>8.1</td>
</tr>
<tr>
<td>Urinary</td>
<td>0.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Male reproductive</td>
<td>0.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Female reproductive</td>
<td>0.5</td>
<td>11.6</td>
</tr>
</tbody>
</table>

Results

Most and least difficult organ systems

At the end of the course, students reported in an online survey what organ system they thought was most difficult to learn and what organ system they thought was least difficult to learn. As shown in Table 2, more than 61% of students reported that some aspect of the nervous system was the most difficult organ system to learn, with the peripheral nervous system (30.8%) being reported most often. Outside of the nervous system, the muscular system (13.1%) was reported most often as the most difficult organ system to learn. Conversely, Table 2 shows that the least difficult organ systems were the cardiovascular system (27.8%), the skeletal system (24.7%), and the female reproductive system (11.6%).

Emergent themes from student written responses

To determine why students perceived organ systems as most or least difficult to learn, students explained their reasoning in an online end of course survey. A total of 198 comments describing the most difficult organ system were analyzed and an identical number of comments describing the least difficult organ system were analyzed. After an iterative coding process, nine themes emerged that were applicable to why students thought organ systems were most or least difficult to learn. A summary of the themes is shown in Table 3 including the definition and a representative quote for each theme.

Table 3. Emergent themes from analyzing written student comments.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Definition</th>
<th>Example quote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>Quantity of material to learn in the system</td>
<td>“There were a lot of structures and functions that went along with this system and if you didn’t know it then it would be hard to follow the rest of section.”</td>
</tr>
<tr>
<td>Complexity</td>
<td>How complex (or simple) the system was</td>
<td>“I think it was mostly difficult to put the pieces together; I feel that I understand material well if I can see that I can retain it, but with material from the central nervous system, I’m constantly forgetting details, all of which are important.”</td>
</tr>
<tr>
<td>Familiarity</td>
<td>Prior exposure to the system</td>
<td>“I think it helped tremendously that I went over this in physiology before.”</td>
</tr>
<tr>
<td>Interest</td>
<td>Enjoyment/personal interest in the system</td>
<td>“I am very active in working out and lifting weights so it was easy to correlate my workouts with the muscles we learned (and ones I was already familiar with) to the actions and functions.”</td>
</tr>
<tr>
<td>Structure</td>
<td>Issues with system structures</td>
<td>“This was the most challenging because of the locations of the nerves and their paths/destinations.”</td>
</tr>
<tr>
<td>Function</td>
<td>Issues with system functions</td>
<td>“The difference between muscular vs cutaneous innervations of spinal nerves were hard for me to grasp.”</td>
</tr>
<tr>
<td>Terms</td>
<td>Issues with system terms (language)</td>
<td>“The terminology and naming the muscles was a little difficult for me to memorize.”</td>
</tr>
<tr>
<td>Time</td>
<td>Amount of time required to learn system</td>
<td>“With the brain itself, it is so complex and complicated that it took me a lot of time to understand it.”</td>
</tr>
<tr>
<td>Visualization</td>
<td>Being able to see system structures and/or use physical models</td>
<td>“I think it was the easiest because I could identify it on myself and it was easily identifiable on the skeleton models in lab.”</td>
</tr>
</tbody>
</table>
Student perceptions of most difficult organ systems
To determine why students perceived certain organ systems as most difficult, written comments were sorted by organ systems and themes were applied to each comment. The fraction of student comments that were tagged with each theme is shown in Table 4 for the four most difficult organ systems (data for the remaining organ systems are provided in the Supplement).

The most difficult organ system reported by students was the peripheral nervous system (Table 2) and the most common themes for why students thought it was difficult were issues with structure and function. Students commented that there was a level of inherent difficulty in identifying and describing the structures and functions of the peripheral nervous system. They also had difficulty connecting the two systems, as in muscular innervation. Reasons for difficulty in learning the central and autonomic nervous systems were similar to those of the peripheral nervous system but a larger number of students cited issues with visualizing the autonomic nervous system. For example, students stated that they had trouble visualizing how signals traveled through the sympathetic trunks to their destinations. They felt that if more detailed models were present in the anatomy laboratory this issue may have been alleviated.

Students who reported that the muscular system was the most difficult to learn cited issues with structure and function (e.g. location of muscles and what motions they produced). More than half of students also commented that the number of muscles that they were required to know was large. In this course, students were required to describe 41 muscles by location and function.

Student perceptions of least difficult organ systems
To determine why students perceived certain organ systems as least difficult, written comments were sorted by organ systems and themes were applied to each comment. The fraction of student comments that were tagged with each theme is shown in Table 5 for the four least difficult organ systems (data for the remaining organ systems are provided in the Supplement). In contrast to the most difficult organ systems (Table 4), in which themes were applied fairly uniformly across organ systems (i.e. difficulties with structure and function), the reasons for why students thought specific organ systems were least difficult were very diverse.

The cardiovascular system was reported by many students to be the least difficult system to learn (Table 5). The most common theme for why students thought it was least difficult was because it was familiar to them (Table 5). Students reported prior learning associated with the cardiovascular system, notably in a required pre-requisite human physiology course. Students who chose the skeletal system as least difficult to learn commented that all they had to do was learn the specific bones and their markings. They mentioned that they had access to skeleton models in the laboratory portion of the course for visualization of the skeletal system, which made it easier to learn the required material. Reasons given for why the female reproductive system and the digestive system were least difficult to learn included familiarity with the system, lack of complexity, and ease of visualization.

Table 4. Coding analysis of students’ comments regarding the most difficult organ systems. The number of students who chose each organ system as most difficult is shown (n). The table reports the percentage of these students whose written comment included a given theme. Since some written comments had more than one theme applied, the percentages do not add up to 100% for each organ system. Data are shown for the four most difficult organ systems (data for the remaining organ systems are shown in the supplementary material).

<table>
<thead>
<tr>
<th>Theme</th>
<th>Peripheral nervous (n = 61)</th>
<th>Central nervous (n = 53)</th>
<th>Autonomic nervous (n = 53)</th>
<th>Muscular (n = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>42.6</td>
<td>37.7</td>
<td>31.0</td>
<td>53.8</td>
</tr>
<tr>
<td>Complexity</td>
<td>45.9</td>
<td>43.4</td>
<td>48.3</td>
<td>11.5</td>
</tr>
<tr>
<td>Familiarity</td>
<td>6.6</td>
<td>3.8</td>
<td>3.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Interest</td>
<td>0.0</td>
<td>0.0</td>
<td>3.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Structure</td>
<td>65.6</td>
<td>60.4</td>
<td>51.7</td>
<td>65.4</td>
</tr>
<tr>
<td>Function</td>
<td>45.9</td>
<td>41.5</td>
<td>37.9</td>
<td>65.4</td>
</tr>
<tr>
<td>Terms</td>
<td>1.6</td>
<td>7.5</td>
<td>17.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Time</td>
<td>8.2</td>
<td>5.7</td>
<td>6.9</td>
<td>7.7</td>
</tr>
<tr>
<td>Visualization</td>
<td>18.0</td>
<td>9.4</td>
<td>34.5</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Continued on next page
Discussion

Students enrolled in this undergraduate human anatomy course overwhelmingly reported that the nervous system was the most difficult organ system to learn due to issues relating to its complex structure-function relationships. These results agree with previous studies in which medical and dental students reported that neuroanatomy was one of the most, if not the most, difficult anatomical topic to learn (Parkin and Rutherford 1990, Kramer and Soley 2002). To a lesser extent, students reported that a lack of models and difficulty visualizing nervous system structures contributed to difficulties learning the nervous system. As being able to visualize anatomical structures through models or dissections has been shown repeatedly to benefit student learning (Kramer and Soley 2002, DeHoff et al. 2011, Lujan et al. 2013, Haspel et al. 2014, Lombardi et al. 2014), it does not come as a surprise that students would report this issue with regards to learning the nervous system. Indeed, undergraduate human anatomy students strongly favor the use of models when learning anatomy (Wright 2012, Anderton et al. 2016, Shaffer 2016).

Having found that students perceive the nervous system to be the most difficult organ system to learn allows for the development or incorporation of pedagogical strategies that can address the perceived problems. To address issues with structure-function relationships, activities may be developed that more explicitly link the connection between the function of the nervous system and the structures it acts on. For example, students cited that muscular innervation was a difficult concept to comprehend. A possible activity that could be used is to have students draw the descending pathway that upper- and lower-motor neurons are involved in to provide somatic motor innervation to a specific muscle. Additionally, clay modeling (Waters et al. 2005, DeHoff et al. 2011, Haspel et al. 2014) could be used to model spinal nerves traveling from the spinal cord to specific muscles. Shaffer (2014) previously developed a laboratory activity in which students use yellow string to model the paths of cranial and spinal nerves through the body by attaching the “nerves” to a skeleton model. These activities may thus help alleviate the issues with complex structure-function relationships and lack of visualization that students found when learning the nervous system.

Conversely, students found that the cardiovascular system was the least challenging organ system to learn primarily because of their prior exposure to this system via a human physiology pre-requisite course. Additionally, students are often exposed to the cardiovascular system (especially the heart) earlier in life and thus may acquire familiarity with the system over time, which may contribute to their perception of the cardiovascular system as less challenging to learn. To understand what students knew about the human body, Reiss and Tunnicliffe (2001) asked students (ranging from four-years-old to first-year undergraduate students) to draw what is inside the human body. They found that 93% of students drew some aspect of the cardiovascular system (nearly always the heart), which was the most commonly drawn organ system. This finding highlights that students of all ages are frequently exposed to the cardiovascular system, which again may contribute to students' familiarity with the system.

Some students found that the skeletal system was least challenging to learn primarily because it was easy to visualize either through palpating bones on their own bodies or by using skeleton models in the laboratory. This result is not surprising, as prior studies have reported that visualization is a critical component for successful learning of anatomy. Pandey and Zimitat (2007) reported that medical students identified that visualization was important towards successfully learning anatomy, in addition to understanding and memorization. Van Wyk and Rennie (2015) found that the majority of medical

\[ \text{Table 5. Coding analysis of students' comments regarding the least difficult organ systems. The number of students who chose each organ system as least difficult is shown (n). The table reports the percentage of these students whose written comment included a given theme. Since some written comments had more than one theme applied, the percentages do not add up to 100% for each organ system. Data are shown for the four least difficult organ systems (data for the remaining organ systems are shown in the supplementary material).} \]

<table>
<thead>
<tr>
<th>Theme</th>
<th>Cardiovascular (n = 55)</th>
<th>Skeletal (n = 49)</th>
<th>Female reproductive (n = 23)</th>
<th>Digestive (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>1.8</td>
<td>8.2</td>
<td>26.1</td>
<td>18.8</td>
</tr>
<tr>
<td>Complexity</td>
<td>23.6</td>
<td>51.0</td>
<td>30.4</td>
<td>50.0</td>
</tr>
<tr>
<td>Familiarity</td>
<td>90.9</td>
<td>18.4</td>
<td>78.3</td>
<td>62.5</td>
</tr>
<tr>
<td>Interest</td>
<td>5.5</td>
<td>12.2</td>
<td>21.7</td>
<td>6.3</td>
</tr>
<tr>
<td>Structure</td>
<td>0.0</td>
<td>10.2</td>
<td>4.3</td>
<td>12.5</td>
</tr>
<tr>
<td>Function</td>
<td>1.8</td>
<td>0.0</td>
<td>0.0</td>
<td>6.3</td>
</tr>
<tr>
<td>Terms</td>
<td>1.8</td>
<td>4.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Time</td>
<td>0.0</td>
<td>4.1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Visualization</td>
<td>7.3</td>
<td>44.9</td>
<td>0.0</td>
<td>18.8</td>
</tr>
</tbody>
</table>

\[ \text{continued on next page} \]
students favored a dissection-approach to learning human anatomy. Dissection was not only applicable to their training but it also helped them visualize the structures of the body. In addition, a variety of models (plastic, animal tissue, computer, etc) have been reported to be useful for learning human anatomy in several different contexts (Lombardi et al. 2014) since models help students place objects or structures into forms that are more readily learned in a visual setting (Gilbert and Boulter 1998).

**Limitations**

A possible limitation of this study is that the data were collected with only one course design, topic sequence, and student population. The course was taught using high structure (Shaffer 2016) which required students to extensively prepare prior to each day of class by reading their textbook and completing graded pre-class assignments. Students also were engaged in active learning exercises in class to test their knowledge. In a course design with less structure (i.e. fewer pre-class assignments or less in-class active learning), students may find different organ systems as most or least difficult because they are learning about them in different ways.

Additionally, the organ systems were covered in a systemic fashion starting with the integument, then skeletal, then muscular, etc, as is the norm in most undergraduate human anatomy textbooks. There could be a temporal effect related to the order that the organ systems were taught that could influence student perceptions of organ systems. Teaching human anatomy regionally or changing the order of organ systems would allow for the determination if the order of topic presentation affects student perceptions of difficulty.

Lastly, this study only assessed one population of students at a large research-intensive university in the southwestern United States. The results of this study may vary if students from different populations, based on geographic location, institution type (e.g. community colleges), and course type (e.g. institutions where anatomy is a required course) are surveyed.

A second limitation is that the course in which this study took place required a human physiology pre-requisite course for enrollment. Therefore, students had prior knowledge of human physiology, especially of the cardiovascular, respiratory, digestive, and urinary systems, which often includes many aspects of human anatomy. This pre-requisite likely influenced the outcomes of this study, as >90% of students who chose the cardiovascular system as least difficult cited familiarity with the system as a reason why they thought it was relatively easy to learn about. This could explain the discrepancy with prior results showing that undergraduate students in an introduction human anatomy and physiology course found the cardiovascular system to be most difficult (Gopal et al. 2010).

Additionally, while the nervous system is taught in undergraduate human physiology courses, it is often taught focusing on neuron anatomy and physiology. Gross nervous system anatomy may be limited in undergraduate human physiology textbooks (Silverthorn 2016). In this case, the lack of prior familiarity with the anatomy of the nervous system may contribute to student perceptions of its difficulty. Repeating this study in introductory human anatomy courses that do not require a human physiology pre-requisite course would be warranted to determine the impact of prior knowledge on students’ perceptions of anatomical organ systems.

Finally, students often cited the ability to work with anatomical models (the visualization theme) as a reason why the skeletal system was least difficult and the lack of models as a reason why the autonomic nervous system was most difficult. The availability of physical anatomical models in the laboratory portion of this course may thus have influenced the outcome of this study. While fully articulated and disarticulated skeletal models were available for student use, there were limited models of nervous system structures, mostly limited to those present in torso models with exposed brains and spinal columns. If additional and more descriptive nervous system models were available, students may have perceived the autonomic nervous system as less difficult to learn.

**Conclusion**

Student perceptions of difficulty in learning organ systems in a human anatomy course were evaluated in this study to determine why students think certain organ systems are more or less difficult than others. The major findings that students perceive complex structure-function relationships in the nervous system as most difficult and the skeletal system and cardiovascular system as least difficult, will allow for the development and incorporation of instructional activities and tools that can help address these problematic areas.

**Acknowledgment**

The authors would like to thank the graduate student teaching assistants of this human anatomy course for their dedication to teaching and student learning.
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Rebekah M. Lieu, RN, BSN earned her bachelor’s degree in Nursing Science from the University of California, Irvine. She is pursuing a career in pediatric nursing.

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Literature cited


continued on next page


Sturges, D and Maurer, TW (2013) Allied Health Students’ Perceptions of Class Difficulty: The Case of Undergraduate Human Anatomy and Physiology Classes. The Internet Journal of Allied Health Sciences and Practice 11. Article 9.


The Effect of Excess Dietary Sugar on Body Systems

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Abstract
Sugar is a pervasive additive in most processed foods. It is disguised behind a plethora of names on food labels, making it difficult for consumers to identify its presence. Excess sugar is a main factor causing metabolic syndrome and it is implicated in several other diseases such as Type 2 diabetes, nephritis, and osteoarthritis. The biochemistry of how sugar affects neurons makes sugar a difficult substance to give up. It is our hope is that you will be encouraged to educate your students on how sugar can be gradually, systemically, and prematurely harmful to the body. doi: 10.21692/haps.2018.012

Key words: sucrose, fructose, metabolic syndrome

The information presented in this article will enhance student comprehension of what makes up a healthy diet and their appreciation for the ubiquitous nature of sugar and processed food in the typical American diet. It will shed light on related nutritional concepts associated with the pedagogy of courses in Human Anatomy and Human Anatomy and Physiology.

Introduction
Sugar as a food additive has the ability to disrupt body systems. Unfortunately, it is difficult to avoid because it is found in almost every processed food. Compounding the situation, there is evidence to suggest that sugar is even more addictive than cocaine (Lenoir et al. 2007). Avoiding sugar, therefore, is paramount for the health of our students and the lives they touch.

Educating students about sugar requires teaching them how to locate sugar on food labels. It also requires teaching them how sugar compromises body systems. This knowledge empowers students to make informed choices. We hope that you will utilize this literature review to freshen your lectures, promote discussion, and perhaps to design class activities.

Finding Sugar on Food Labels
Sugar has over 50 names, so locating it on a food label can be challenging. Teaching students to read labels is a good first step in understanding how much sugar has infiltrated our diet. A lecture can begin by showing an ingredient label from an unidentified food item. Students are instructed to locate sugar on the ingredient list and then guess the food item. This gets students thinking about ingredients.

<table>
<thead>
<tr>
<th>Barley malt</th>
<th>Castor sugar</th>
<th>Evaporated cane juice</th>
<th>Lactose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beet sugar</td>
<td>Coconut sugar</td>
<td>Florida crystals</td>
<td>Maple Sugar</td>
</tr>
<tr>
<td>Blackstrap molasses</td>
<td>Confectioner's sugar (powdered sugar)</td>
<td>Fruit Juice</td>
<td>Muscovado sugar</td>
</tr>
<tr>
<td>Brown Rice Syrup</td>
<td>Corn syrup</td>
<td>Fruit juice concentrate</td>
<td>Panela sugar</td>
</tr>
<tr>
<td>Brown sugar</td>
<td>Corn syrup solids</td>
<td>Glucose</td>
<td>Raw sugar</td>
</tr>
<tr>
<td>Buttered syrup</td>
<td>Date sugar</td>
<td>Glucose solids</td>
<td>Refiner's syrup</td>
</tr>
<tr>
<td>Cane juice crystals</td>
<td>Demerara sugar</td>
<td>Golden syrup</td>
<td>Rice syrup</td>
</tr>
<tr>
<td>Cane sugar</td>
<td>Dextrose</td>
<td>Grape sugar</td>
<td>Sorghum syrup</td>
</tr>
<tr>
<td>Caramel</td>
<td>Diastatic malt</td>
<td>Honey</td>
<td>Sucanat</td>
</tr>
<tr>
<td>Carob syrup</td>
<td>Ethyl maltol</td>
<td>Icing sugar</td>
<td>Yellow sugar</td>
</tr>
</tbody>
</table>

Figure 1. Sucrose Charades. Avoiding sugar begins with recognizing its many names (Bjarnadottir, 2017).
If students are not reading labels, they may believe they are making nutritious food choices because they do not realize that common items like tomato sauce, salad dressing, pickles, catsup, bread, and meat products are loaded with sugar.

**Carbohydrates**
Nutritionally speaking, there is no such thing as an “essential” carbohydrate. In fact, there are groups of healthy people who exist quite robustly without them. For example, the Inuit people of Alaska have subsisted on a strictly protein and fat diet for centuries as a result of minimal vegetation in the arctic region (Gadsby and Leon 2004). These indigenous peoples still have normal blood glucose levels (Gahagan 2014). While most carbohydrates consumed are converted to glucose, proteins and lipids can also be converted to glucose by the liver (Rui 2014). This understanding sets the stage for how other macromolecules can be used to fuel the body. The use of sugar as a main ingredient for energy production is a relatively new trend in human history.

**Sugar and Metabolism**
Many traditional diets of the past included a small amount of carbohydrates that broke down into a single monosaccharide, glucose. Today, however, many if not most, fast foods or prepackaged foods contain sucrose or high fructose corn syrup, which break down into two monosaccharides, glucose and fructose. This introduces excessive fructose into the modern diet in addition to the more traditional starches that have historically been present. Excessive fructose is metabolized differently from the fructose that naturally occurs in fruit. Natural fruit fructose contains fiber to slow absorption, allowing the liver time to convert fructose to glucose.

Sucrose contributes to nonalcoholic fatty liver disease (NAFLD) in both animal and human studies (Lambertz 2017). Researchers observed indiscernible pathological changes in rat livers when comparing diets of sucrose and ethanol (Best et al. 1949). Other research has documented an association between the intake of sugar-sweetened beverages and the risk of developing NAFLD (Ma et al. 2015). Most sodas contain sucrose and high fructose corn syrup. Most fruit juices contain fructose. When either is added to a meal, a deluge of fructose drenches the liver to such a degree that hepatocytes cannot keep pace with the conversion of fructose to glucose.

Basic biochemistry informs us that excess fructose intake disrupts and redirects the steps of glycolysis onto the path of lipogenesis (Voet et al. 2013). Current research shows that the modern fructose influx is so vast and the onslaught so intense that hepatocytes convert fructose into metabolites, including lactate and lipids (Sun and Empie 2012). This ignites a cascade of reactions causing de novo liver lipogenesis, leading to insulin resistance, a precursor to metabolic syndrome (Basaranoglu et al. 2015). Metabolic syndrome is a group of risk factors including excess abdominal fat, hypertension, hyperglycemia, insulin resistance, and elevated cholesterol levels. In combination, these risk factors considerably increase the chance of developing metabolic diseases such as Type 2 Diabetes (O’Neill et al. 2015).

**Sugar and The Endocrine System**
In a healthy human body, the hormone insulin facilitates the process of glucose transport into cells. As blood glucose levels rise due to the consumption of carbohydrates or the breakdown of proteins or lipids for energy, the pancreas secretes an appropriate amount of insulin to shuttle the glucose into cells (Samuel and Shulman 2012). Glucose is received by cells all over the body, fueling cellular processes, replenishing glycogen stores in the muscle and liver, and/or being stored as fat for later use. Maintaining high insulin sensitivity by consuming high quality fats, proteins and complex carbohydrates, allows the pancreas to have very precise responses to blood glucose rises. However, in a modern diet, the blood becomes inundated with glucose due to constant snacking on high glycemic load foods such as highly refined carbohydrates and sugar-sweetened beverages. This forces the pancreas to work harder to produce enough insulin in order to decrease blood glucose.

Eventually, the cells become less responsive to the chronically high levels of insulin attempting to deliver glucose to them, a condition known as insulin resistance. Adipose cells are the one type of cell that are always able to accept excess glucose and thus, the connection between insulin resistance and lipogenesis is made (Samuel and Shulman 2012).

Lipogenesis and chronically high levels of insulin in the blood are both inflammatory processes. As inflammation spreads throughout the body, the body becomes susceptible to metabolic syndrome (Monteiro and Azevedo 2010). Previously, excess adipose tissue was thought to be caused by consuming too much fat. Recent evidence suggests that sugar is the culprit (Kearns et al. 2015). An increase in adipose tissue is a precursor for metabolic diseases.

**Sugar and Collagen**
Sugar is sticky. Glycation is the process by which sugar in the body spontaneously sticks to or binds to other macromolecules and hardens, aging the tissue. An analogy of candy getting stuck in hair, causing the hair to lose its bounce and flow, can be used to explain how sugar glycates body tissue. In addition, glycated proteins accelerate free radical cascades, which ultimately lead to the death of cells (Sakasai-Sakai et al. 2017).

Collagen, a complex braided protein with varying amino acid chains and side chains, accounts for a third of the body’s total protein (Shouders and Raines 2009). The ingestion of sugar disrupts the function of collagen and its ability to regenerate. Poorly made and maintained collagen can wear away joints and lead to arthritis. It can glycate the endothelial walls of blood vessels, which leads to cardiovascular disease (Peiro et al. 2017).
and disrupt the adhesion of cellular junctions, which causes premature wrinkles (Harrison and Rijani 2015).

Sugar is a glycotoxin that can form advanced glycation end products (AGEs) that build up over time. AGEs cause proteins, like collagen, to fold improperly and lose their flexible nature (Gkogkolou et al. 2012). Sugar is pro-inflammatory (Ahmed et al. 2005 and Peiro et al. 2016). Glycation and inflammation can be seen in vasculature as well as the glomerular basement membranes (Peiro et al. 2016). Consuming a diet high in sugar accelerates the progress of diseases such as Type 2 Diabetes, nephritis, and osteoarthritis (Gkogkolou et al. 2012).

Sugar and The Central Nervous System
Excess sugar consumption causes dopamine receptors in the brain to become overtaxed. This can cause addiction, which eventually leads to neurodegeneration (Blum et al. 2014). Sugar also negatively affects neurogenesis in babies causing delayed motor skill ability (Jamel et al. 1996 and Anderton et al. 2002).

Hemoglobin A\textsubscript{1c} is a biomarker used to estimate blood glucose levels over the 90 days prior to the drawing blood. It can be used to correlate blood sugar oscillations over time with diseases such as diabetes and Alzheimer’s. A 2012 study found that high blood glucose, as measured by Hb A\textsubscript{1c}, correlated with cognitive decline (Perlmutter 2013 and Yaffe et al. 2012). In fact there is data supporting the link between diabetes and Alzheimer’s disease (Perlmutter 2013). In 2008, de la Monte and Wands concluded that the term ‘Type 3 diabetes’ accurately reflects the fact that Alzheimer’s Disease may represent a form of diabetes that selectively involves the brain and has molecular and biochemical features that overlap with both Type 1 and Type 2 diabetes mellitus (Perlmutter 2013).

Sugar and The Skeletal System
Several studies have shown an association between bone health and sugar consumption. Compared with girls who did not consume carbonated beverages, those girls that included carbonated beverages in their diet, specifically colas, were two times more likely to suffer a bone fracture (Wyshak 2000). Research in hamsters demonstrates that when diet is adjusted to high-sucrose consumption (>50% of calories), bone thickness and volume both decrease. These changes are indicative of osteoporosis (Saffar et al. 1981).

Sugar and Dentition
It has been well documented that sucrose causes dental caries in humans by feeding the bacteria, Streptococcus mutans (Lin and Burne 2013). Here we have a classic case of humans remedying a problem (dentists “fix” cavities) instead of getting at the root cause and preventing it. Why not stop consuming sugar to avoid cavities all together?

Sugar and The Immune System
When healthy volunteers ingested 100 grams (less than a two liter bottle of coke) of sugar in the form of sucrose, glucose or fructose, the capacity of their neutrophils to engulf bacteria decreased (Sanchez et al. 1973, Ringsdorf et al. 1976).

Sugar and The Kidney
Studies have shown that refined sugar consumption causes increased urinary calcium excretion, which has been identified as a contributing risk factor of kidney stone development (Lemann et al. 1969). A study in women found a higher incidence of kidney stones among those women in the highest group of sugar intake when compared to those in the lowest group (Curhan et al. 1997).

Sugar and The Respiratory System
Asthma is a chronic condition in which respiratory airways are compromised making breathing difficult. It can cause symptoms such as: coughing, wheezing and shortness of breath (Martinez et al. 2013). In 2008 a study suggested that a diet high in sugar sets the stage for inflammation in the respiratory tract which lead to the symptoms associated with asthma (Kierstein et al. 2008).

Conclusion
Sugar abounds in the typical modern diet in ways previously unheard of in the history of humankind. The susceptibility of collagen to glycation and the oppression of the liver by fructose are but two examples of how systemic deterioration occurs in the body when it is sustained on a diet of processed food that is high in sugar and low on nutritive value. Describing basic biochemistry could motivate students to make better food choices, in order to avoid the metabolic diseases caused by excessive sugar consumption.

It is evident that excessive sugar is detrimental to the human body and there is reason to believe that it may be addictive. Promoting awareness and teaching how to read food labels are life skills and may even be a lifesaver for students.
As a teaching community, we should try to educate our students about the effects of excess sugar consumption. Our collective efforts could benefit the bodies and minds of students and perhaps help to stem the tide of developing metabolic disease, which is on the rise worldwide.

About the Authors
Bridgit Goldman has been teaching college level biology since 1998. She has a PhD in Cellular, Molecular, and Developmental Biology from The Graduate School and University Center of The City University of New York. Since 2007 she has designed, developed and taught all the lecture and laboratory classes in Human Anatomy and Physiology at Siena College.

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San Diego Miramar College

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The travel expenses are not included in the 3-credit tuition for this course. See website for more details.

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Patrick Eggena, MD

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