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Differences in Item Statistics Between Positively and Negatively Worded Stems on Histology Examinations

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Abstract
Multiple-choice questions (MCQ) are commonly used on histology examinations. There are many guidelines for how to properly write MCQ and many of them recommend avoiding negatively worded stems. The current study aims to investigate differences between positively and negatively worded stems in a medical histology course by comparing the item difficulty and discrimination index between matched MCQs. When questions were matched by modified Bloom’s Taxonomy classification, presence or absence of an image, and timing of content presentation, negatively worded lower level Bloom’s questions were less difficult and had a lower discrimination index. https://doi.org/10.21692/haps.2019.025

Key Words: negative questions, multiple-choice questions, item writing flaws, stem orientation, histology

Introduction
Item Writing Flaws and Negative Questions
Multiple choice question (MCQ) based examinations are a popular form of student assessment that is common among undergraduate and professional school programs. Some of the perceived benefits of using MCQs have been detailed in Table 1. There are a number of guidelines for properly writing MCQs. Haladyna, Downing, and Rodriguez (2002) have compiled a list of 31 item-writing recommendations from educational measurement textbooks. These recommendations include:

1. Avoid testing on trivial content.
2. Format items vertically instead of horizontally.
3. Use correct grammar, punctuation, and spelling.
4. Include the central idea in the stem and not in the answer choices.
5. Ensure there is only one correct answer.
6. Keep answer choices independent from one another.
7. Avoid questions with “all-of-the-above” as an answer choice.

The National Board of Medical Examiners (NBME), which is responsible for writing items for the United States Medical Licensing Examination® (USMLE®) three-step examinations, has also published MCQ guidelines (Case and Swanson 2002). The NBME addresses issues related to “testwiseness” such as the inclusion of grammatical cues, logical cues, using absolute terms like always or never, and having the correct answer include the most elements in common with the other options. The NBME also cautions item writers to avoid issues related to irrelevant difficulty, which includes using long, complicated answer options, using vague frequency terms like sometimes and rarely, and using questions with “none-of-the-above” as an answer choice (Case and Swanson 2002).
Questions that fail to adhere to item-writing guidelines can be described as having item-writing flaws (IWFs). When using a list of 15 item-writing guidelines, a medical school found that 8% of their examination questions suffered from IWFs (Ware and Vik 2009). Another medical school using the 31 guidelines compiled by Halayna et al. (2002), discovered that as many as 36-65% of MCQ on a series of four examinations from different disciplines were flawed (Downing 2005). Similarly, Tarrant and Ware (2008) found that 47% of items were flawed on ten high stakes nursing examinations. These high rates of IWF are alarming and have also been shown to affect student examination performance. For instance, Downing (2005) found that because of the IWFs, as many as 10-15% of the students may have been incorrectly classified as having “failed”. On the other hand, Tarrant and Ware (2008) reported that students on the borderline of passing or failing performed better on an examination when flawed items were present compared to when the flawed items were removed. In both of these studies, flawed items may have led to unfair and inaccurate assessment of students’ learning.

An item-writing guideline that continues to be debated is the use of negatively worded questions. These are question stems that include the words “not”, “except”, or “incorrect”. The NBME recommends against using these questions because the answer choices cannot easily be ranked on a continuum. This increases the difficulty and inhibits the examinee’s ability to rank answer choices as “most” or “least” correct (Case and Swanson 2002). Others agree that negatively worded question stems should be avoided since they make the question unnecessarily difficult and confusing by forcing the examinee to change their tactics from finding the correct answer to finding the incorrect answer (Boland et al. 2010; Smith 2018).

The recommendation to avoid negative questions has been supported by a number of studies. Harasym et al. (1992) found that when comparing single response negatively worded and multiple response positively worded questions, multiple response positively worded questions were a more reliable and valid method of assessing student achievement. Additionally, negative questions have been associated with a lower Bloom’s Taxonomy level, meaning they do not require the examinee to use higher cognitive functions (Maher et al. 2016).

Other studies have suggested that there is no harm in utilizing negative questions if item-writers highlight, bold, or underline the negation (Haladyna et al. 2002). Results in an early study on this topic found no difference in item difficulty or discrimination index when comparing negatively and positively worded question stems (Violato and Marini 1989). These results were confirmed by Caldwell and Pate (2013), which found that while negatively worded questions had higher item difficulty the difference did not reach statistical significance. There was also no significant difference in the discrimination index of the positively and negatively worded questions, however, the study compared only five pairs of negatively and positively worded questions (Caldwell and Pate 2013).
Assessing MCQs

There are a number of ways to assess MCQs. The current study will consider item difficulty, discrimination index (DI) values, and Bloom’s Taxonomy categorizations. Item difficulty can be defined as the percentage of the examinees that answered the question correctly. Thus, the higher the percentage of students who answered the question correctly, the “easier” the question is judged to be (Ebel and Frisbie 1991). Discrimination index is the difference between the percentage of correct responses from the upper and lower performers, which indicates an item’s capacity to discriminate between high scorers and low scorers on an examination (Rush, Rankin, and White 2016). Therefore, a high discrimination index value indicates that the upper performers did better on the item compared to the lower performers. Different values can be used to define upper and lower performers, but often the highest and lowest quartiles are used (Rush, Rankin, and White 2016). A high quality item should be of appropriate difficulty for the students being assessed and should have the capacity to discriminate between students.

Bloom’s Taxonomy is a tool created to assess the cognitive functions and level of reasoning needed to answer a question. The original version consisted of six different levels: the lowest being Knowledge, the levels increase to Comprehension, Application, Analysis, Synthesis, and Evaluation (Bloom 1956). The taxonomy has undergone several revisions since its inception; the first rewording the dimensions to fall under two more generalized categories of “Knowledge and Cognitive Process” (Kratwohl 2002). While the original taxonomy had six dimensions, some claim that the higher levels (Synthesis and Evaluation) cannot be assessed using MCQ (Crowe et al. 2008; Huxham and Naeraa 1980).

Some researchers suggest the original Bloom’s Taxonomy tool may be too general for specific academic disciplines and certain levels of instruction (Hussey and Smith 2002). This limitation has led to the creation of discipline specific Bloom’s Taxonomy tools. One such adaptation is the Bloom’s Taxonomy History Tool (BTHHT), which allows for evaluators to properly categorize histology related MCQs. It also places a larger focus on questions involving images due to the visual nature of histology (Zaidi et al. 2017).

Purpose

Despite conflicting recommendations, negative questions continue to be utilized. Downing (2005) found that negatively worded questions were the second most common IWF on medical school examinations. Other medical schools have reported that 7-23% of examination questions were negatively written (Maher et al. 2016; Ware and Vik 2009). To investigate the appropriateness of using negatively worded question stems, this study aims to compare the item difficulty and discrimination index of positively and negatively worded questions. Our first hypothesis was that compared to positively worded questions stems, negatively worded question stems will be more difficult, meaning that fewer students will correctly answer these questions. Our second hypothesis was that negatively worded stems would have a lower discrimination index value compared to positively worded stems.

Methods

Context

The University of Mississippi Medical Center (UMMC) is a large academic medical center which educates future healthcare providers within the schools of medicine, dentistry, pharmacy, nursing, allied health science, and graduate studies. The medical school is the state’s only allopathic program and typically accepts only in state residents.

At the time of this study, the medical curriculum included two years of basic science courses followed by two years of clinical rotations. First year medical students took Gross Anatomy, Histology and Cell Biology, Developmental Anatomy, Physiology, Neuroscience, Biochemistry, and Introduction to the Medical Profession. Medical Histology and Cell Biology was taught as a stand-alone course throughout the entire fall semester and half of the spring semester. The course consisted of six credit hours and was divided into seven blocks.

Medical Histology and Cell Biology included both lecture and laboratory components. Fifty-minute lectures given by anatomy faculty covered basic histology content and were not mandatory for students to attend. At the end of each of these lectures, a five-question multiple-choice bonus quiz was given using TurningPoint electronic polling software (www.turningtechnologies.com). At the end of each block, each student’s average bonus quiz score was added to their written examination grade as percentage points. Each block also had one clinical correlation lecture, presented by a physician, which connected the basic science content to clinical practice. These lectures were mandatory and did not include a bonus quiz. For laboratory sessions, students were divided into two groups. Each group had an hour and half in the laboratory to work with a partner to identify cells, tissues, and organs using light microscopy and electron microscope images. Students were given a guide for each laboratory session that indicated the structures they should identify. Anatomy faculty members and teaching assistants were also available to answer questions. At the end of each lab students were given a bonus quiz that consisted of five light microscopy questions and one electron microscopy identification question. Each question on the laboratory bonus quiz was fill-in-the-blank style. At the end of each block, each student’s average bonus lab quiz score was added to their practical examination grade as percentage points.
Seven lecture examinations, three practical examinations, and the NBME Histology and Cell Biology Subject Examination were used to determine grades. Lecture exams consisted of 30–36 multiple-choice questions administered using ExamSoft® software (www.examsoft.com). Five answer options were provided for positively worded stems and four were provided for negatively worded stems. In negatively worded questions, the negation was capitalized and bolded. Two clinical vignette questions were also included as extra credit. The practical examination consisted of approximately 60 fill-in-the-blank style questions that required students to identify cells, tissues, and organs using light microscopy and electron microscope images. Students had one minute at each station to view the slide or image and then they rotated to the next station. The average of the seven lecture examinations was worth 45% of the final grade, the average of the three practical examinations was 45%, and the NBME Subject Examination was 10%. Table 2 demonstrates how the average lecture and practical exam grades were calculated.

<table>
<thead>
<tr>
<th>Block</th>
<th>Topics</th>
<th>% of Lecture Grade</th>
<th>% of Practical Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cellular and Molecular Biology</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Basic Tissues 1</td>
<td>15.0</td>
<td>33.87</td>
</tr>
<tr>
<td>3</td>
<td>Basic Tissues 2</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Digestive System and Immune</td>
<td>15.0</td>
<td>32.26</td>
</tr>
<tr>
<td>5</td>
<td>Blood, Ear, and Eye</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cardiovascular, Urinary, Endocrine, and Cell Division</td>
<td>12.5</td>
<td>33.87</td>
</tr>
<tr>
<td>7</td>
<td>Reproductive and Respiratory</td>
<td>15.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Contribution of each exam to the lecture and practical exam grades.

<table>
<thead>
<tr>
<th>Exam</th>
<th># of Exam Takers (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>163</td>
</tr>
<tr>
<td>2</td>
<td>162</td>
</tr>
<tr>
<td>3</td>
<td>163</td>
</tr>
<tr>
<td>4</td>
<td>162</td>
</tr>
<tr>
<td>5</td>
<td>162</td>
</tr>
<tr>
<td>6</td>
<td>157</td>
</tr>
<tr>
<td>7</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 3. Number of ExamSoft® exam takers at each block.

Participants
At the time of the study there were a total of 163 students in the Medical Histology and Cell Biology course. However, the number of students taking the exam using the ExamSoft® software varied between exams due to personal computer issues or absences (Table 3). Students who had computer issues or absences took the exam on paper and were excluded from our calculations.
Materials

Each Histology and Cell Biology question was rated using a modified Bloom's Taxonomy tool (Table 4). This tool was based on the frequently used Revised Bloom's Taxonomy (Krathwohl 2002). Material from the Bloom’s Taxonomy Histology Tool (Zaidi et al. 2017) was also incorporated since it addresses some discipline specific information that is pertinent to histology MCQs. This tool was used by two authors who were anatomy graduate students with prior histology experience (SK and AF). The raters were instructed to make judgments based on the assumption that images and questions were novel to students. Raters were required to assign each item to the Remember, Understand, Apply, Analyze, or Evaluate category. To ensure the tool was being used in a similar manner by both raters, inter-rater reliability was determined using Cohen’s Kappa and a moderate level of agreement was found (Table 5). Questions that were classified differently by the two raters were discussed and agreed upon using the modified Bloom’s Taxonomy criteria.

<table>
<thead>
<tr>
<th>Remember (1)</th>
<th>Recall facts and basic concepts (ex. recall, define, memorize) (Krathwohl 2002).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand (2)</td>
<td>Explain ideas or concepts, without relating to anything else (ex. classify, identify, locate) (Krathwohl 2002).</td>
</tr>
</tbody>
</table>

“Requires recall and comprehension of facts. Image questions asking to identify a structure/cell type without requiring a full understanding of the relationship of all parts” (Zaidi 2017).

<table>
<thead>
<tr>
<th>Apply (3)</th>
<th>Use information in new situations (ex. apply, implement, use) (Krathwohl,2002).</th>
</tr>
</thead>
</table>

“Two-step questions that require image-based identification as well as the application of knowledge (e.g., identify structure and know function/purpose)” (Zaidi 2017).

<table>
<thead>
<tr>
<th>Analyze (4)</th>
<th>Draw connections among ideas (ex. organize, analyze, calculate, compare, contrast, attribute) (Krathwohl 2002).</th>
</tr>
</thead>
</table>

“Students must call upon multiple independent facts and properly join them together.” (Zaidi 2017).

| Evaluate (5) | Justify a decision (ex. critique, judge, predict, appraise) (Krathwohl 2002). |

Table 4. Modified Bloom’s Taxonomy criteria used to classify histology questions.

<table>
<thead>
<tr>
<th>Value Asymptotic Standard Error</th>
<th>Approximate T</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohen’s Kappa</td>
<td>.520</td>
<td>.041</td>
</tr>
</tbody>
</table>

Table 5. Inter-rater reliability for classification of questions using the modified Bloom’s Taxonomy criteria. a: Not assuming the null hypothesis. b: Using the asymptotic standard error assuming the null hypothesis.
Procedure

Lecture examination questions from the 2017 - 2018 school year were retrospectively analyzed. A total of 240 items were classified based on several criteria:

1. The designation of a negative or positive stem.
2. The modified Bloom's Taxonomy rating.
3. The presence or absence of an image relating to the question.
4. The timing of the content presentation.

Question stems using negative phrases such as "Which of the following is NOT…", "All of the following EXCEPT…", or "Identify the FALSE statement" were classified as negatively worded, while all others were classified as positively worded. Next, every question was rated using the modified Bloom’s Taxonomy tool.

In order to match each negative question, the authors first found positively worded question stems with the same modified Bloom’s Taxonomy rating. From this group of positively worded questions, the negatively worded question was then matched with a positively worded question based on the presence or absence of an image. Finally, the negative question was matched based on timing of content presentation. Ideally, content tested in the positive and negative matched questions was presented during the same lecture. If not, the authors moved to a positive question that tested content presented in the same exam block. An example of a matched positive and negative question can be seen in Figure 1.

Item difficulty and discrimination index values were obtained from the ExamSoft® post-test summary report. Item difficulty was calculated as the number of students who correctly answered the item divided by the total number of exam takers. Discrimination index was calculated by subtracting the item difficulty of the lower 27% of the class from the item difficulty of the upper 27% of the class.

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**Figure 1.** Example of matched positive and negative questions. These items were matched based on their modified Bloom’s Taxonomy rating (Apply), the presence of image, and the timing of content presentation (concepts were presented during the digestive system lecture).
Differences in Item Statistics Between Positively and Negatively Worded Stems on Histology Examinations

Analysis

Descriptive statistics were used to summarize question characteristics. Paired t-tests were conducted in order to compare the item difficulty of matched positive and negative questions. To compare discrimination index values, questions were categorized based on the criteria recommended by Roa et al. (2016). This criteria categorizes items with DI values between 0.00-0.19 as “poor”, 0.20-0.29 as “acceptable”, 0.30-0.39 as “good”, and >0.40 as “excellent”. Fisher’s exact tests were then used to compared the likelihood of positive or negative questions having a better DI in the lower (Remember and Understand) and higher (Apply and Analyze) Bloom’s Taxonomy categories. All statistical analyses were completed using SPSS version 24 (IBM Inc., Armonk, NY) with a significance level of p < 0.05.

Results

The majority of questions were classified as Remember (54%) and none were classified as Evaluate. Frequency counts and mean item difficulty of each category is shown in Table 6.

<table>
<thead>
<tr>
<th>Bloom’s Taxonomy Rating</th>
<th>Frequency, n(%)</th>
<th>Item Difficulty (M±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>129 (53.8)</td>
<td>78.74 ± 17.1</td>
</tr>
<tr>
<td>Understand</td>
<td>30 (12.5)</td>
<td>76.20 ± 18.6</td>
</tr>
<tr>
<td>Apply</td>
<td>50 (20.8)</td>
<td>74.04 ± 18.0</td>
</tr>
<tr>
<td>Analyze</td>
<td>31 (12.9)</td>
<td>75.39 ± 15.3</td>
</tr>
<tr>
<td>Evaluate</td>
<td>0 (0.0)</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image</th>
<th>Frequency, n(%)</th>
<th>Item Difficulty (M±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>92 (38.3)</td>
<td>77.99 ± 17.5</td>
</tr>
<tr>
<td>No</td>
<td>148 (61.7)</td>
<td>75.43 ± 16.9</td>
</tr>
</tbody>
</table>

Table 6. Frequency and mean item difficulty of all questions by modified Bloom’s Taxonomy classification and presence or absence of an image.

Of the 240 questions on the seven histology lecture exams, 27 (11.3%) were classified as negatively worded. Each negative question was matched with a positive question based on Bloom’s Taxonomy rating, presence of an image, and timing of content delivery. Only one negative question required matching from a different exam, while all other negative questions were successfully matched with positive questions that tested content presented in the same exam block. Table 7 shows the mean item difficulty of positively and negatively worded questions in each Bloom’s Taxonomy rating.

In order to address our first hypothesis, which stated that negatively worded questions would be more difficult, paired t-tests were conducted to compare item difficulty of the matched positive and negative questions. There was no significant difference in difficulty found between 27 pairs of matched positive and negative questions; t (26) = .884, p=.385. However, when comparing difficulty of positive and negative questions in each Bloom’s Taxonomy category, there was a significant difference in the Remember category; t (15) = 2.258, p=.039. No significant differences were found between positive and negative questions in the Understand category; t (3) = -.545, p=.624 or the Apply category; t (5) = -.037, p=.972. Paired t-test could not be conducted to compare positive and negative questions in the last two categories (Analyze and Evaluate) because there were too few questions or no pairs of questions to analyze.

continued on next page
In order to address the second hypothesis, which stated that negatively worded stems would have a lower discrimination index value compared to positively worded stems, each of the 27 paired questions were placed into a discrimination index category. Table 8 details the discrimination index categories for each pair and which question of the pair received the better DI category. The Fisher’s exact test was then used to compare the likelihood of positive or negative questions having a better DI in the lower (Remember and Understand) and higher (Apply and Analyze) Bloom’s Taxonomy categories. Fisher’s exact test shows no significant association between Bloom’s Taxonomy level and frequency of pairs having a better positive question DI or having equal DI (p = 1.000). Likewise, there was no significant association between Bloom’s Taxonomy level and frequency of pairs having a better negative question DI or equal DI (p = 0.138). However, there was a significant association between Bloom’s Taxonomy level and frequency of pairs having a better positive question DI or better negative question DI (p = 0.014), with positively worded questions tending to have a better DI category when written at a lower Bloom’s Taxonomy level.

<table>
<thead>
<tr>
<th>Bloom’s Taxonomy Rating</th>
<th>Pairs, n(%)</th>
<th>Positive Item Difficulty (M±SD)</th>
<th>Negative Item Difficulty (M±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>16 (59.3)</td>
<td>72.38 ± 16.5*</td>
<td>83.94 ± 17.2*</td>
</tr>
<tr>
<td>Understand</td>
<td>4 (14.8)</td>
<td>81.75 ± 5.1</td>
<td>73.00 ± 31.7</td>
</tr>
<tr>
<td>Apply</td>
<td>6 (22.2)</td>
<td>71.33 ± 19.6</td>
<td>71.00 ± 12.5</td>
</tr>
<tr>
<td>Analyze</td>
<td>1 (3.7)</td>
<td>98.00</td>
<td>61.00</td>
</tr>
<tr>
<td>Evaluate</td>
<td>0 (0.0)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>27 (100.0)</td>
<td>74.48 ± 27.3</td>
<td>78.59 ± 23.6</td>
</tr>
</tbody>
</table>

Table 7. Mean item difficulty of positive and negative questions by Bloom’s Taxonomy rating. *Significant difference at the 0.05 level.
### Table 8.

Discrimination index of paired positively and negatively worded questions by modified Bloom’s Taxonomy rating. The final column indicates whether the positively or negatively worded question of each pair had a better DI. DI = discrimination index.

<table>
<thead>
<tr>
<th>Bloom’s Taxonomy</th>
<th>Pair</th>
<th>Positive DI</th>
<th>Positive Category</th>
<th>Negative DI</th>
<th>Negative Category</th>
<th>Better DI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Remember</strong></td>
<td>1</td>
<td>0.44</td>
<td>Excellent</td>
<td>0.23</td>
<td>Acceptable</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.31</td>
<td>Good</td>
<td>0.21</td>
<td>Acceptable</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.36</td>
<td>Good</td>
<td>0.20</td>
<td>Acceptable</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.21</td>
<td>Acceptable</td>
<td>0.23</td>
<td>Acceptable</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.61</td>
<td>Excellent</td>
<td>0.33</td>
<td>Good</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.25</td>
<td>Acceptable</td>
<td>0.05</td>
<td>Poor</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>0.05</td>
<td>Poor</td>
<td>0.11</td>
<td>Poor</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0.53</td>
<td>Excellent</td>
<td>0.00</td>
<td>Poor</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>0.26</td>
<td>Acceptable</td>
<td>0.41</td>
<td>Excellent</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>0.04</td>
<td>Poor</td>
<td>0.02</td>
<td>Poor</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>0.27</td>
<td>Acceptable</td>
<td>0.09</td>
<td>Poor</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.16</td>
<td>Poor</td>
<td>0.29</td>
<td>Acceptable</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>0.01</td>
<td>Poor</td>
<td>0.15</td>
<td>Poor</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>0.55</td>
<td>Excellent</td>
<td>0.29</td>
<td>Acceptable</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>0.19</td>
<td>Poor</td>
<td>0.21</td>
<td>Acceptable</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>0.30</td>
<td>Good</td>
<td>0.17</td>
<td>Poor</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Understand</strong></td>
<td>17</td>
<td>0.27</td>
<td>Acceptable</td>
<td>0.00</td>
<td>Poor</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0.36</td>
<td>Good</td>
<td>0.29</td>
<td>Acceptable</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>0.25</td>
<td>Acceptable</td>
<td>0.24</td>
<td>Acceptable</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.28</td>
<td>Acceptable</td>
<td>0.09</td>
<td>Poor</td>
<td>Positive</td>
</tr>
<tr>
<td><strong>Apply</strong></td>
<td>21</td>
<td>0.10</td>
<td>Poor</td>
<td>0.34</td>
<td>Good</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.49</td>
<td>Excellent</td>
<td>0.36</td>
<td>Good</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>0.40</td>
<td>Excellent</td>
<td>0.48</td>
<td>Excellent</td>
<td>Same</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>0.16</td>
<td>Poor</td>
<td>0.42</td>
<td>Excellent</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>0.14</td>
<td>Poor</td>
<td>0.28</td>
<td>Acceptable</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>0.35</td>
<td>Good</td>
<td>0.42</td>
<td>Excellent</td>
<td>Negative</td>
</tr>
<tr>
<td><strong>Analyze</strong></td>
<td>27</td>
<td>0.03</td>
<td>Poor</td>
<td>0.45</td>
<td>Excellent</td>
<td>Negative</td>
</tr>
</tbody>
</table>

### Table 9.

Frequency of pairs with the positively worded question having a better DI, pairs with negatively worded question having a better DI, and pairs with equal DI categories; separated by lower (Remember and Understand) and higher (Apply and Analyze) Bloom’s Taxonomy categories. For example, of the lower Bloom’s Taxonomy pairs, in 12 of the 20 pairs the positively worded question had a better DI. DI = discrimination index.

<table>
<thead>
<tr>
<th>Bloom’s Taxonomy</th>
<th>Better Positive DI (n)</th>
<th>Same DI (n)</th>
<th>Better Negative DI (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Blooms</strong></td>
<td>12</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Higher Blooms</strong></td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>
Discussion

There is still some debate about whether negative questions are appropriate to use on MCQ examinations (Haladyna et al. 2002). In order to investigate this issue we compared the item difficulty and discrimination index of 27 pairs of positively and negatively worded question stems. Our first hypothesis was that compared to positively worded questions, negatively worded questions would be more difficult. This hypothesis was not supported by our data. When comparing the mean item difficulty of all positive and negative questions there were no significant differences found. However, when comparing matched questions from the same Bloom’s Taxonomy category, there was a significant difference in item difficulty between positively and negatively worded questions in the Remember category, with negative questions being less difficult. The low level Remember questions consist mostly of true or false fact answer options. The lack of complexity in these options may limit the variety of distractors in these questions, making it easier for students to identify the false answer option.

These results contradict the findings of Caldwell and Pate (2013) and Violato and Marini (1989) that claimed there was no significant difference in item difficulty of positively and negatively worded stems on pharmacy or undergraduate MCQ examinations. However, these studies did not compare positively and negatively worded questions within Bloom’s Taxonomy levels and therefore potential differences at certain levels may have been overlooked.

Our data also revealed a trend that shows as the Bloom’s Taxonomy classification of negative questions becomes higher; fewer numbers of students answered the question correctly. A future investigation may consider analyzing a larger sample of negative questions in order to see if this trend persists.

Our second hypothesis was that negatively worded stems would have a lower discrimination index value compared to positively worded stems. This hypothesis was only somewhat supported by our data. At the lower level Bloom’s Taxonomy questions there were significantly more pairs of questions where the positive question had a better DI categorization compared to the negative question. Once again, these results differ from the findings of Caldwell and Pate (2013) and Violato and Marini (1989).

These results indicate that negatively worded questions written at a lower level were easier for students, since more students correctly answered these questions, and tended to have a lower DI as compared to matched positively worded questions. Therefore, negative questions at a lower Bloom’s level may not be as effective at differentiating between high and low performing students. For this reason, our results seem to support the widely held belief that negative question stems should be avoided when possible, particularly when evaluating lower levels of knowledge based on Bloom’s Taxonomy (Boland et al. 2010; Harasym et al. 1992; Smith 2018; Xu et al. 2016).

There are several limitations to the current study. Because the questions were analyzed retrospectively, we were only able to control for a limited number of variables; specifically Bloom’s Taxonomy classification, the presence or absence of an image, and the timing of content presentation. Future studies may consider matching questions prior to administration of the exam in order to make questions identical in all ways except the negation of the stem. Secondly, due to small numbers of questions categorized at higher Bloom’s taxonomy levels, trends in this data may have been overlooked. Future studies should aim to include a sufficient number of pairs of positive and negative questions at each Bloom’s taxonomy level. Finally, due to faculty members’ perceived difficulty of negatively worded questions, only four answer options were provided for these questions while positively worded questions had five answer options. Once again, future studies should consider prospectively designing questions in order to create questions that are similar in all ways except stem negation.

The current study found that compared to positively worded questions at a low Bloom’s level, negatively worded questions of the same level are significantly easier and have a lower DI category. This suggests that negative questions may not be ideal for differentiating between high and low performing students, particularly on lower level Bloom’s questions. Based on these results, instructors may want to limit their use of negatively worded questions on MCQ examinations. However, further research is needed to confirm these preliminary findings.

About the Authors

Sara Klender, BS, is a fourth-year graduate student in the Clinical Anatomy program at the University of Mississippi Medical Center (UMMC). Her dissertation research focuses on the relationship between fear of death and performance in gross anatomy.

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continued on next page
References


“I got hired to a full-time, tenure-track position and it was exactly what I was dreaming I would find when I enrolled in the MSHAPI program. ... The MSHAPI program is the best thing I could have chosen to do, not just for the degree and the doors that opened, but for the content and quality of the program that has prepared me so well for this new role.”

– Jeremy E. Miller ’17, NYCC MSHAPI Graduate

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- **VALUE:** MSHAPI prepares highly skilled professionals to teach in a wide variety of instructional settings and environments.
- **QUALITY:** MSHAPI faculty are highly respected and include a past Human Anatomy and Physiology Society (HAPS) president and three recipients of HAPS’ President’s Medal award.
- **UNIQUE:** Part content expertise and part pedagogy development, the MSHAPI program provides students with the knowledge and skills they need to become in-demand anatomy and physiology instructional specialists.
Using Paper Models to Teach Basic Concepts of the Human Musculoskeletal System

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Abstract
Traditionally, human anatomy is taught using cadaveric human or animal specimens, however such materials are not always available or are quite costly. Alternate instructional methods can include software, models, clay models, and illustrations. Unfortunately, while cost effective, these methods lack the ability to demonstrate the in situ three-dimensional relationships between anatomical structures. This study examined one alternative method of instruction, the construction of three-dimensional paper models, which are currently limited in availability, and mostly designed for teaching medical anatomy programs. This study set out to determine 1) if a paper model system could be used to highlight the anatomic complexity of specific anatomic regions, 2) if a model system primarily designed for medical anatomy programs could be customized to topics and made appropriate for undergraduate anatomy courses, and 3) if this low-technology and inexpensive form of instruction is an effective tool in teaching musculoskeletal anatomy. Students were given a series of four models to assemble during a time period of 4-weeks. Students were assessed with a series of paired questions before and after the model exercise relating to: number of muscles, plane of muscle, depth of structure, name and function of muscle. Comparison of the pre and post-test data demonstrated a gain in knowledge. Thus, the utilization of paper models are a viable and cost effective pedagogical tool for undergraduate anatomical education. https://doi.org/10.21692/haps.2019.024

Key Words: paper models, 3D anatomy, musculoskeletal system, undergraduate

Introduction
Anatomy and Physiology is a popular course taught at many undergraduate institutions, and is often a prerequisite for graduate-level professional health programs. Cadaveric dissection (human or animal) has been the traditional paradigm of anatomical pedagogy since the days of the Renaissance (McLachlan and Patten 2006; Gosh, 2015). While teaching methods have varied over the years, anatomy and physiology courses continue to primarily utilize animal or human cadaver dissection to teach anatomic structure. However, the primacy of cadaver-based anatomy instruction has not gone unchallenged. These challenges include: questioning the educational value of the time spent in the dissection laboratory rather than studying the material, the usefulness of utilizing embalmed tissues, the environmental hazards involved with formalin fixation, the financial and infrastructural costs associated with the use and storage of formalin fixed cadaveric material, as well as the ethical, moral, and other practical issues that arise with the use of cadaveric material (McLachlan et al., 2004; McLachlan and Patten 2006; Wright, 2012).

While cadaveric dissection is still a primary method of anatomical pedagogy, many traditional dissection-based laboratories are transitioning to more cost and time effective methods of instruction (McDaniel and Daday, 2017). Moreover, cadaveric material may not always be available or affordable, especially at smaller undergraduate institutions. As a result, alternative pedagogical methods are sought in the anatomical sciences. Common and currently utilized alternative methods of anatomical instruction include: anatomy software packages (Wright, 2012), plastic models (Preece et al., 2013), clay models (Motoike et al., 2009), and anatomic illustrations (Bell and Evans, 2014). Unfortunately, while more cost effective than cadaveric dissection, these alternative methods of anatomy instruction lack the flexibility of the human cadaver and eliminate the student’s ability to visualize three-dimensional structures in situ. Comparative strengths and weaknesses of each type of anatomical education are briefly summarized in Table 1.
Using Paper Models to Teach Basic Concepts of the Human Musculoskeletal System

There is an additional method of instruction for anatomy education, which is the construction and use of three-dimensional paper models. Paper model systems currently exist. However these models are designed specifically for medical students, include complex details, and require reading a complicated set of instructions in order to assemble the model (Weber, 1979; Locket et al., 2012). In undergraduate introductory level courses where students have limited course time to devote to anatomical descriptions, limited resources, and variable levels of pre-requisites, the utilization of the current paper model system would be inappropriate. However, the utilization of a paper model system is intriguing because it can address several of the previously mentioned weaknesses presented by other forms of anatomical instruction. First, because it is a paper model, it is inexpensive and pre-prepared. Second, because it allows for the study of anatomic structures at different layers and depths, it generally preserves the three-dimensional relationships between various anatomic structures. Third, the students have to assemble the paper models, resulting in an active hands-on interactive learning activity. Finally, because this is a paper model system there are no ethical concerns, environmental hazards, or need for expensive technological or other institutional infrastructure.

<table>
<thead>
<tr>
<th>Method</th>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadaveric dissection</td>
<td>Dissection Skills&lt;br&gt;Active form of Learning&lt;br&gt;Exposure to a vertebrate body&lt;br&gt;3D relationships easily observed&lt;br&gt;Anatomic variation is appreciated</td>
<td>Requires low student to faculty ratio&lt;br&gt;Dissection is time intensive&lt;br&gt;Environmental Hazards&lt;br&gt;Cost Intensive to Institutions&lt;br&gt;Ethical and Moral issues</td>
</tr>
<tr>
<td>Clay models</td>
<td>3D structure&lt;br&gt;Students make their own body&lt;br&gt;Highly interactive</td>
<td>Intensive training of faculty and students&lt;br&gt;Requires low student to faculty ratio&lt;br&gt;Requires self-motivated students</td>
</tr>
<tr>
<td>Illustrations</td>
<td>Allows for easy to identify coloration, and isolation of structures&lt;br&gt;Can show depth with multiple illustrations&lt;br&gt;Relatively inexpensive&lt;br&gt;Easy to study</td>
<td>Artistic stylization of anatomy&lt;br&gt;Illustrations may be incorrect&lt;br&gt;Copyright/legal issues&lt;br&gt;Loss of 3D visualization &amp; relationships&lt;br&gt;Loss of anatomic variation&lt;br&gt;Passive form of learning</td>
</tr>
<tr>
<td>Plastic models</td>
<td>Easy to handle&lt;br&gt;3D structures&lt;br&gt;Can enlarge structures too small to adequately study in situ&lt;br&gt;Easy to study&lt;br&gt;Interactive (depending on the model)</td>
<td>Expensive&lt;br&gt;Loss of associations between muscles and bones&lt;br&gt;Cannot show deep muscles&lt;br&gt;Model Keys may be incorrect&lt;br&gt;Artistic stylization of anatomy&lt;br&gt;Loss of anatomic variation</td>
</tr>
<tr>
<td>Software</td>
<td>Uses technology&lt;br&gt;Can be accessed outside class room&lt;br&gt;Real time quizzing&lt;br&gt;Interactive programs</td>
<td>Expensive programs&lt;br&gt;Access to Computer Technology&lt;br&gt;Loss of 3D visualization &amp; relationships&lt;br&gt;Limited interaction with specimens&lt;br&gt;Technological ability of Faculty&lt;br&gt;Loss of anatomic variation</td>
</tr>
</tbody>
</table>

*Table 1. Current Utilized Methods of Anatomic Instruction*
To address the need for alternate instruction methods, in this study we set out to investigate three primary questions:

1. Could the paper model system effectively highlight and teach the complexity of the musculoskeletal system for four different regions of the human body?
2. Could a paper model system designed to teach medical students be adapted to a complexity level appropriate for undergraduate students?
3. Could this inexpensive, low tech, hands-on model system achieve a significant gain in student learning on a complex topic like the musculoskeletal system?

This study also investigated whether specific demographics (major, SAT score, etc.) had an impact on the effectiveness of this teaching tool.

Materials and Methods

The research protocol (protocol # 2016-045-17-A) for this study was submitted to the Slippery Rock University Institutional Review Board. It was determined to be exempt for the requirement for IRB review and approval, per exemption according to 45 CFR 46.101(b)(1) for research conducted in established education settings involving normal education practices such as research on the effectiveness of curricula.

Population

The paper model system was tested on six sections of Biology 217, Anatomy and Physiology II, at Slippery Rock University for a total sample size of 140 students. As illustrated in Figure 1A, the vast majority of students, 76.43%, were female. As shown in Figure 1B, a majority of the students, 48.57%, had declared exercise science as their major, while 45% of the students were public health majors. The remaining 6.43% of students were other declared majors such as biology, histotechnology, and cytotechnology. The class year of students varied from underclassmen to upperclassmen, and included students who were first-experience students as well as course-repeating students. Students SAT scores were acquired through the office of institutional research.

Paper Models

Four different regions of the human body, the abdomen, brachium, face, and anterior thigh, were studied over a four-week period during one semester. The paper models used in this study were derived from two different sources. Paper models for the brachium and anterior thigh were from Locket et al. (2012). The nerves and arteries of the two paper model systems were omitted from this study. Since the brachium and anterior thigh models were originally designed to teach anatomy at a medical school level, they were developed to be anatomically proportional, contain a high degree of fine detail, and be accompanied by a complex set of assembly instructions. Moreover, due to the fine level of anatomic detail, the names of the muscles were written on the paper adjacent to the pieces of the model, that were eventually to be cut out (Locket et al. 2012).

Models for the abdomen and face, although inspired by the Locket et al. (2012) paper model system, were created by one of the authors (S. Rehorek) and specifically designed for undergraduate level instruction. Thus, the S. Rehorek models were intentionally designed to be simple and clear with less concern for anatomic proportionality and a lesser degree of fine detail. They included a set of assembly instructions that were simple and easy to follow. More importantly, the names of the muscles were either written on the model pieces (abdominal model), or the muscle abbreviations were written on the models pieces (face model). Each set of models included a key to the abbreviations in the model activity packet. Models were printed on normal weight copy paper, left uncolored, and an instruction sheet on model assembly was provided. Lines indicating muscle fiber directionality were sketched on all of the models.

A Class by Gender

23.57

76.43

Male Female

B Class by Major

6.43

48.57

ES PH Other

45.00

Figure 1. Demographic data of the anatomy and physiology II class. The demographic breakdown of the student population in the Biology 217: Anatomy and Physiology with Lab II course. (A) The percent of students identified by gender. (B) The percentage of students in declared majors. ES = exercise science, PH = public health, Other = students enrolled in the biology major, or one of the many pre-health profession programs (e.g. biology, histotechnology, and cytotechnology).

Figure 2. The abdominal muscles model. This partially deconstructed picture of the model components shows the elements used and the simplicity of the design.
Activity
During the musculoskeletal portion of the course, students were given one of the four different paper models (abdomen, brachium, face, or anterior thigh) based upon the specific body region being covered that week. Students were given a packet that included the pieces of the paper model and the instruction sheet, along with the scissors and glue sticks necessary to complete the activity. Students were then instructed to color the individual pieces of the paper model for easy identification and to follow the instructions for cutting out the individual pieces of the model. The instructions for assembling the models were given after the students had cut out the pieces of the model. A completed model was available for students to observe. Students were given an hour to complete construction of the model. Students were asked to compare their newly constructed three-dimensional paper model to the plastic anatomical models available in the anatomy lab.

Assessment of Knowledge
Prior to the beginning of the musculoskeletal unit in the Anatomy and Physiology II course, students were given a pre-test to assess their base knowledge. The scored pre-tests were not returned to students, and the correct answers to the pre-test questions were not reviewed or discussed, so that students could not memorize the questions and answers. The assessment of base anatomical knowledge was done because students majoring in exercise science had already taken an introductory musculoskeletal anatomy course, whereas students majoring in public health and the other majors had not. Following the conclusion of the study of each body region in class, student knowledge was again assessed on each of the body regions, using the same pre-test questions. As shown in Table 2, the assessment questions were designed to cover five basic areas of knowledge:
1. The number of muscles learned.
2. The names of structures.
3. The function of structures.
4. The plane of the muscles.
5. The depth of the structures.
All tests, pre and post, consisted of five multiple choice questions, and were therefore graded and reported out of five points.

Assessment of Student Confidence
A total of three questions were designed to determine student confidence in their own knowledge of the material. Confidence was assessed for the abdomen, brachium, and face utilizing a Likert scale of 1 to 5, with 1 designated as not confident, and 5 designated as very confident. As indicated in Table 3, the three questions assessed ability to identify muscles, ability to understand the layering of the muscle, and the ability to connect the structure of the muscle to its function. Unfortunately, because of the timing of the lab activities in the semester, confidence data for the anterior thigh could not be assessed because the post-test items for this anatomic region were covered on the final exam, and not available for inclusion in this study.

Table 2. Topic Questions Designed to Test Anatomic Knowledge

<table>
<thead>
<tr>
<th>Topic of question</th>
<th>Rationale for questions</th>
<th>Example question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of muscles</td>
<td>To test to see if students understand that there are multiple muscles in any given region</td>
<td>How many pairs of abdominal muscles are there?</td>
</tr>
<tr>
<td>Plane of muscle</td>
<td>To test to see if students understand that muscle fibers are orientated in a specific manner</td>
<td>The fibers of which muscle are perpendicular to the sagittal plane?</td>
</tr>
<tr>
<td>Depth</td>
<td>To see if students understand that muscles are arranged in a 3D manner</td>
<td>Which muscle is the deepest?</td>
</tr>
<tr>
<td>Name of structure</td>
<td>To see if students understand that muscles are associated with names and structures.</td>
<td>Which muscle forms part of the radial groove?</td>
</tr>
<tr>
<td>Muscle function</td>
<td>To see if students understand the function of a given muscle</td>
<td>Which muscle causes hip flexion?</td>
</tr>
</tbody>
</table>

Table 3. Questions Designed to Assess Confidence of Student’s Knowledge

<table>
<thead>
<tr>
<th>Topic of question</th>
<th>Rationale for question</th>
<th>Question asked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Muscle identity</td>
<td>To determine student perception of regional muscle identity confidence</td>
<td>How confident do you feel about being able to identify facial/abdominal or arm muscles?</td>
</tr>
<tr>
<td>Layering</td>
<td>To determine if students understood that muscles are layered</td>
<td>How confident do you feel about understanding the different layers of muscles?</td>
</tr>
<tr>
<td>Connecting structure to function</td>
<td>To determine if students understand that muscle fibers orientation dictates muscle function</td>
<td>How confident do you feel about understanding the role of planes in muscle function?</td>
</tr>
</tbody>
</table>
Using Paper Models to Teach Basic Concepts of the Human Musculoskeletal System

Student Perception of the Paper Models
At the end of the semester, as part of the student course evaluation process, students were asked three questions designed to assess the student perception of the paper model activity. The student course evaluation process is anonymous so the responses to the questions regarding student perception of the paper model activities could not be used to identity individual students or cohorts. As seen in Table 4, the questions assessed whether the students liked the activity, which model the student found to be the most helpful, and which model the student found to be the least helpful.

Data Analysis
All the data were analyzed using SigmaPlot 13.0. The significance for all tests was determined to at least a P-value of <0.05. The specifics of each statistical analysis can be found in the results and analysis section.

Results and Analysis
Students demonstrated an overall gain of knowledge utilizing the paper model system
One of the main objectives of this study was to determine if a paper model system initially designed for students in a medical anatomy program could be appropriately customized and used to teach anatomy in an undergraduate setting. To determine the effectiveness of the paper models as a teaching tool, students were given a pretest to assess their base knowledge prior to building and studying the paper model and a post-test following construction and studying of the paper model. Student performance on the post-tests was compared to determine on which post-test students performed the best. First the post-test for the four different paper models were analyzed using the Kruskal-Wallis one-way analysis of variance. This analysis showed a significant (P<0.001) difference between the results of the post-tests. Further post-hoc testing revealed that the students' post-test performance on the abdomen was significantly better than their post-test performance on any of the other anatomical regions. Post-hoc testing did not find any significant post-test performance difference between the face, brachium, or anterior thigh anatomic regions.

Analysis of the pre and post-test data began with the Shapiro-Wilk test for normality, which generated a value of P<0.05, indicating that the data was not normally distributed. Therefore, the data was analyzed utilizing the Wilcoxon signed rank test, revealing a significant (P<0.001; Figure 3a) difference between the pre and post-test data for all four of the models studied. In order to determine which of the paper model systems demonstrated the largest learning gain, the difference between pre and post-test results was analyzed using a Kruskal-Wallis one-way analysis of variance on ranks. Overall, a significant (P<0.001) difference in student learning gain was observed between the different anatomical model systems. Tukey post hoc testing revealed no difference when comparing the learning gain between the two Locket models.

Table 4. Questions Designed to Assess Student Perception of the Paper Model Activity

<table>
<thead>
<tr>
<th>Topic of question</th>
<th>Rational for question</th>
<th>Question asked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helpfulness of paper model activity</td>
<td>To determine if the students felt this approach enhanced their learning experience</td>
<td>I found the use of paper models helped me learn the muscles of the body</td>
</tr>
<tr>
<td>Most Helpful Model</td>
<td>To determine student preference of specific models</td>
<td>I found _____ to be the most helpful</td>
</tr>
<tr>
<td>Least Helpful Model</td>
<td>To determine student preference of specific models</td>
<td>I found _____ to be the least helpful</td>
</tr>
</tbody>
</table>

Figure 3. Pre and post-test performance on anatomical knowledge questions. (A) Student acquisition of knowledge was assessed using a series of pre-test questions, administered prior to using a paper model, and a post-test following using a paper model. Pre-and-post-test results were reported out of a score of five. (B) The learning gain was determined by taking the post-test score and subtracting the pre-test score to determine the overall difference. The gain in student learning was then compared between the different model activities. Error Bars = SEM, ** = Significance (P<0.001), # = Significance (P≤0.05)
Using Paper Models to Teach Basic Concepts of the Human Musculoskeletal System

(brachium vs. anterior thigh), or the learning gain between the two author-designed models (face vs. abdomen). However, a significant (P<0.05) difference in learning gain was found when the abdomen model was compared to either the brachium or anterior thigh model (Figure 3b; Table 5), and a significant (P<0.001) difference in learning gain was found when the face model was compared to either the brachium or anterior thigh models (Figure 3b; Table 5).

<table>
<thead>
<tr>
<th>Comparison</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdomen vs. Brachium</td>
<td>0.03</td>
</tr>
<tr>
<td>Abdomen vs. Anterior Thigh</td>
<td>0.05</td>
</tr>
<tr>
<td>Brachium vs. Anterior Thigh</td>
<td>0.998</td>
</tr>
<tr>
<td>Face vs. Abdomen</td>
<td>0.077</td>
</tr>
<tr>
<td>Face vs. Brachium</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Face vs. Anterior Thigh</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 5. Comparison of Learning Gain Performance by Anatomic Region

While learning the identification of anatomic structures was important, it was only one component of the intended activity. Other learning goals included the understanding of applications (function, depth, plane, and number). The data demonstrates that the paper model system is an effective pedagogical method for teaching anatomy, especially in preserving the three dimensional relationships of the anatomic areas of study. The pre and post-test data for the individual task areas (name, function, depth, plane, and number) were analyzed utilizing a Kruskall-Wallis one-way analysis of variance, and as illustrated in Figure 4, a significant (P<0.001) increase in overall student performance was observed for each task areas. The overall student post-test data was again analyzed to determine which of the task areas had the greatest increase utilizing the Kruskal-Wallis one-way analysis of variance on ranks, followed by a Tukey post-hoc analysis. Analysis of the data revealed a significant (P<0.001) difference in task performance, with the results of the post-hoc testing being shown in Table 6. Three of the four comparisons utilizing the task area of depth (Table 6) were found to be significant (P<0.002), strongly indicating preservation of the three-dimensional anatomical concepts. Comparisons using function and plane were also found to be significant when compared to other non-three-dimensional task related areas (Table 6). However, further analysis into the performance on specific questions revealed no consistent relationship between the anatomical regions and the task area questions.

Figure 4. Pre and post-test performance on task area questions. Student acquisition of anatomical concepts was assessed (for all paper models) using a series of task specific designed pre-test questions, administered prior to using a paper model, and followed by a post-test after using a paper model. Pre- and post-test results were reported out of a score of five. Error Bars = SEM, ** = Significance (P<0.001)
Using Paper Models to Teach Basic Concepts of the Human Musculoskeletal System

Potential Factors Impacting the Learning Gain

A large majority (93.57%) of students in the Anatomy and Physiology II class had declared either exercise science or public health as their primary major (Figure 1). Therefore, an analysis was conducted to see if there was an effect of the student’s declared major on the post-testing results. First the data was analyzed utilizing the Shapiro-Wilk normality test, resulting in a calculated test statistic of 0.093; indicating the data demonstrated a normal distribution. Following the normality test, the post-test data between the exercise science majors and the public health majors was analyzed utilizing a 1-tailed t-test. As illustrated in Figure 5, a significant (P<0.001) difference in the post-test performance was found, with the exercise science majors outperforming the public health majors in all four of the anatomic areas that were studied. The results of this analysis clearly demonstrated that the declared major has a significant effect on student post-test performance.

A majority of students enrolled in the Anatomy and Physiology II course identify as female, Figure 1a. Therefore we wanted to determine if student gain was influenced by the identified gender of the student. First, the data was analyzed with the Shapiro-Wilk test for normality. This analysis determined (P<0.05) that the data were not normally distributed. The data were further analyzed by the non-parametric Mann Whitney test, which demonstrated that the gender of a student had no significant (P=0.051) effect on the learning gain from this paper model system.

Finally we wanted to determine if there was a correlation between student SAT scores and their performance on the paper model activity. When the pre-test data was analyzed against the student SAT scores there was no significant correlation. However, when post-test results were compared to student SAT results, we found a significant (P=0.004) correlation with the coefficient of determination ($r^2$) to be 0.058, meaning that a student’s SAT scores can explain 5.8% of the variation observed in the data.

These findings indicate that declared major had the greatest impact on the overall learning gains. SAT scores have a correlation with the learning gains and identified gender had no impact on the learning gains observed in this activity.

### Table 5. Comparison of Post-test performance by Question Task Area

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<td><strong>Depth vs. Number</strong></td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td><strong>Function vs. Number</strong></td>
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<tr>
<td>Function vs. Plane</td>
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<tr>
<td>Name vs. Number</td>
<td>0.981</td>
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<tr>
<td><strong>Plane vs. Name</strong></td>
<td>0.013</td>
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### Figure 5. Influence of a student’s declared major on post-test performance. A student’s declared major was found to have a significant influence on the post-test outcomes. Two majors (public health and exercise science) make up an overwhelming majority of the Biology 217 class population. The overall pre-test and post-test results between these two majors were directly compared. ES = exercise science, PH = public health. Error Bars = SEM, *** = Significance (P<0.0001)

The Paper Model System altered student Confidence

Student confidence level with the anatomical information was assessed using the series of questions posed in Table 3. First, the data was analyzed with the Shapiro-Wilk test for normality, which determined (P<0.05) that the data was not normally distributed. Therefore, the Wilcoxon signed rank test was used to analyze the pre-test/post-test data for the abdomen, brachium, and face. As illustrated in Figure 6a, there were significant (P<0.001) increases in student confidence for content regarding the abdomen, brachium, and face. When it came to the three-dimensional task area questions (Figure 6b), there were significant (P<0.001) increases in student confidence for content regarding muscle layering and anatomical planes.

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that no correlation (abdomen P=0.389; brachium P=0.234; and face P=0.234) to academic success was demonstrated. So, even though using the paper model system demonstrated significant gains in student learning and had a positive effect on student confidence, the increase in student confidence with the material did not correlate to a better or worse academic performance in any specific anatomical region studied.

**Student Perception of the Paper Model Activity**

In order to assess student perception of the paper model laboratory activity, and which model system they found the most and least helpful, students were surveyed at the end of the course. Student satisfaction with the paper models was evaluated by posing the questions that are presented in Table 4, and then having the students respond using a Likert scale of 1 to 5, with 5 designated as strongly agree, and 1 being strongly disagree. As seen in Figure 7a, a large majority 71.7% of students agreed or strongly agreed that the paper models helped them learn, while a relatively smaller portion of the students 28.3% stated that the paper models were not helpful to their learning.

Students were also asked which model was the most and least helpful in their studies. As seen in Figure 7b, 43.5% of the students surveyed (N=140) found the face musculature model to be the most helpful, with the abdominal musculature model coming in a close second at 38%. Interestingly, the two Locket models came in a distant third and fourth with 15% of the students finding the brachium model helpful, and only 3% finding the anterior thigh model helpful (Figure 7b). With regard to the model that was the least helpful, the data was much more split. 14.5% of students surveyed found both the face and abdominal muscle models to be least helpful. As expected, based on the previous assessment, the Locket models were found to be the least helpful of the paper models, with 28.2% of students identifying the anterior thigh model as least helpful, and 22.1% of students identifying the brachium model as least helpful.

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**Figure 6.** Paper models systems effect on student confidence. Questions assessing student confidence with anatomical knowledge were asked on both the pre-tests and post-tests. (A) Student confidence with general anatomical knowledge in three of the four body regions studied. (B) Student confidence with knowledge in two of the three task area questions specifically designed to assess the dimensional concepts. Error Bars = SEM, ** = Significance (P<0.001)

**Figure 7.** Student’s perception of the paper model activities. (A) Assessment of the overall student perception on how helpful the paper model activities were in learning anatomy. (B) Body region specific assessment on which paper model activities were the most helpful in learning anatomy, and which models were the least helpful in learning anatomy. SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree
Discussion

Our data revealed that there was a gain in student learning, and that regardless of pre-requisite there was the same absolute level of knowledge gain. Therefore, this study demonstrates that not only can a paper model system be designed to a complexity level appropriate for an undergraduate student, but also that paper models are an inexpensive viable pedagogical tool for anatomical education.

One of the more challenging issues that face anatomy educators is which combination of pedagogical systems (images, models, cadaveric) is the most appropriate to teach anatomical concepts. More importantly, to teach the anatomical concepts at a level of detail appropriate for college undergraduates, many of whom are taking undergraduate anatomy and physiology courses as prerequisite classes for entry into health professions training programs. Studies have focused on the success of using a multimodal approach (e.g.: using models, clays, digital media, body painting etc.) to best teach students (Sugand et al., 2010; Higazi, 2014) and accommodate a multitude of learning strategies (Soon, 2015). To our knowledge, this study is the first of its kind to examine the effects of a three-dimensional paper model system on undergraduate anatomical sciences education, as another pedagogical technique.

The first question of this study was, could a paper model system effectively highlight and teach the complexity of the musculoskeletal system for four different regions of the body? Overall the results from this study clearly indicate that a significant amount of student learning occurred when this model system was used to teach the complexity of detail that is involved with musculoskeletal anatomy. Typically, the three-dimensional attributes of musculoskeletal anatomy are better appreciated in cadaveric dissections (Papa and Vaccarezza, 2013). However, when it comes to pedagogical effectiveness, students do not necessarily find cadaveric dissection to be the best teaching tool (Bergman et al., 2011). Evaluation of student knowledge in the task areas designed to assess the complex three-dimensional anatomical relationships revealed a significant gain in student knowledge in the concepts areas of muscle depth, plane, and function (Figure 6). Significant gains in student knowledge of muscle depth, plane, and function all indicate that a paper model system can be an effective pedagogical tool to teach three-dimensional anatomic relationships.

The second question this study set out to answer was, could a paper model system originally designed to teach medical students, be adapted to a complexity level appropriate for undergraduate students? The results of this study demonstrate that a) this paper model system can be modified for instructional purposes at an undergraduate level and b) data from this study offer suggestions on how to adapt these models for use at an undergraduate level. Students found both of the Locket models (brachium and anterior thigh) to be the least helpful, while finding the two models designed by Dr. S. Rehorek (abdomen and face) to be the most helpful (Figure 7). The face and abdominal models were designed to be simpler, and composed of larger pieces, which allowed for easier to manipulation. Additionally, the assembly instructions for the face and abdomen models were concise and clear preventing confusion and frustration, resulting in an overall more enjoyable activity. The brachium and anterior thigh models adapted from Locket had many small pieces, and complex assembly instructions, which increased student frustration and confusion during the assembly of the models.

The ability to simplify the paper models to a level more appropriate for undergraduate education is important, because as has been documented in the pedagogical research, students respond better to activities if they are more fun (Higazi, 2014). Additionally, placement of the muscle names was also found to affect student learning, with labels on the actual muscles (Rehorek models) being more helpful than those labeled outside of the muscles (Locket), which would often get lost during construction. Repetition and engagement with the material is key to any successful learning strategy (Dunn-Lewis et al., 2016).

The last question this study examined was, can this inexpensive, low tech, interactive model system achieve a significant gain in student learning for a complex topic like the musculoskeletal system? There were significant learning gains in all four anatomic regions studied (Figure 3) and functional task areas (Figure 4). This seems to indicate that significant learning gains took place using a relatively simplistic, inexpensive, and more importantly, an environmentally safe model system. Additionally, allowing students to take these models home opens up additional self-study time for that would otherwise not be available. Self-study time is becoming more of a necessity as the amount of material that needs to be taught is outpacing the amount of time available for study, thus making self-study an increasing viable form of learning (Bergman et al., 2011).

One of the most dramatic findings in this study was the impact that a student’s declared major had on the learning gain with this paper model system. Here at Slippery Rock University, there are no official prerequisite courses for a student to register for the Anatomy and Physiology II course. Most of the students in the class are either exercise science majors or public health majors. The students enrolled in exercise science are required, as an unofficial prerequisite, to take an semester-long exercise science course titled “Applied Anatomy” which is a basic musculoskeletal anatomy class, whereas the public health majors typically are not required to take this course. There was a significant difference between the exercise science students, who had taken the applied anatomy class, and the public health students who had not taken the course. The results of the study demonstrated that the exercise science students outperformed the public health
majors on three of the four paper models (face being the exception) in both pre-and-post testing (Figure 5). When the pre-test data for the face was examined both majors showed equivalent levels of performance. However, when the post-test data for the face was examined, while both the exercise science and public health majors showed a significant increase in their performance, the exercise science majors significantly outperformed the public health students (Figure 5). This model system would suggest that exercise science majors are better prepared to process and retain the information with regard to muscle anatomy and the three dimensional aspects of the muscular anatomy. This would be a reasonable conclusion, based on the fact the course on “Applied Anatomy” teaches not only the basic linguistic jargon that accompanies musculoskeletal anatomy, but also primes the students at a basic level in some of the other concepts of muscle planes, actions, and regional relationships. The effect of a prerequisite course on anatomy and physiology grades has been noted (Russell et al., 2016), but those were for general science courses, not specifically human anatomical courses. The precise mechanism for why the exercise science majors outperform the public health majors has yet to be precisely elucidated. However, it is very clear from the data presented in this study, that the declared major of a student has a profound effect on their performance in Anatomy and Physiology II.

Regardless of the reason for the variable performance in the different models, one thing was clear, that is that the amount of class time dedicated to the models needs to be proportionate to the complexity of building the model. For example, the face model which is fairly simplistic to color, cut, and assemble does not need the same amount of laboratory time as the construction of the anterior thigh or brachium model. The major reason the time dedicated to model building must be tailored to the complexity of the model is that if too much time is allotted to a model that is simple to build, the students will get bored and their attention will wander. On the other hand, if there is not enough time allowed for building a complex model, the students will rush through it and get frustrated, which decreases the overall effectiveness of the activity.

Different pedagogical methodologies have been used for anatomic science education. While the cadaver or cadaveric materials historically represents the best teacher of anatomy, there are still the institutional infrastructure costs to run such laboratories, and environmental hazards, such as formaldehyde exposure, that need to be considered. The paper models presented in this study provided an inexpensive, nontoxic, and mostly hazard free system in which to teach anatomy. Moreover, because these anatomic models are three-dimensional in nature, the anatomic relationships that are best appreciated in the cadaveric teaching material is preserved to a large degree. Additionally, because the students are actively building these models, not just passively observing anatomic models, this is a much more active learning pedagogical practice that involves a tactile component not just a strictly cognitive component.

This finding while interesting also has a confounding variable that needs to be taken into consideration. Did students underperform in the brachium/anterior thigh model? If so, why? The “Applied Anatomy” course focuses most of its time on the musculoskeletal anatomy of the upper and lower extremity. Since exercise science majors form the majority of students registered in the Anatomy and Physiology II course, there is a chance that this finding could be biased by the fact that exercise science majors are already somewhat familiar with the anatomy of the extremities. This familiarity with the anatomy of the extremities, may have given the students a false sense of confidence (figure 6a), thus tempering their study of a body region they already felt comfortable with. This is called the overconfidence effect, when there is a disparity between what students know and what they think they know (Nowell and Alston, 2007). This is an issue of retrieval of information, not learning, in which students have learned the material and thus no longer feel the need to actively remember it (Karpicke and Grimaldi, 2012). This results in under preparation and subsequently underperformance (Nowell and Alston, 2007). Muscles of the abdomen and face are not the focus of study in the applied anatomy course, thus the abdomen and face models presented in this study would present a novel learning opportunity to the students. Therefore, the novelty of the learning experience would tend to increase the student’s focus and study of the new region.

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This study clearly demonstrates that a paper model system that was originally designed for students in medical training programs can be used to teach undergraduate anatomy. However the models have to be adapted for students at the undergraduate level in order to have a successful result.

Acknowledgements
The authors of this study would like to gratefully acknowledge the assistance provided by Drs. Dean DeNicola and Simon Beeching, Slippery Rock University Department of Biology and Dr. Dilrukshika Singhabahu, Slippery Rock University Department of Mathematics and Statistics for their assistance with the study design and computation of the statistics.
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A Novel Three-Dimensional Drawing Activity to Learn the Dural Venous Sinuses

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Abstract
Drawing as a pedagogical tool in anatomy has been shown to be effective at increasing knowledge and engaging students. Therefore, a three-dimensional drawing activity of the dural venous sinuses was implemented to increase knowledge of the structures and improve understanding of their spatial orientation and drainage. Students were given a pre-test, listened to a lecture, performed the activity, and completed a post-test. For this activity, students working in pairs were given markers and white swim caps and instructed to draw the sinuses on their partner’s swim cap with anatomical accuracy. Results from the post-test revealed a significant increase in knowledge related to the structure and drainage of the dural venous sinuses. Students found that drawing was an effective way to learn anatomical structures and strongly agreed that translating a two-dimensional picture into a three-dimensional drawing improved their understanding of anatomical orientation. Overall, this was a quick, effective activity utilizing three-dimensional drawing to solidify the understanding of the dural venous sinuses. https://doi.org/10.21692/haps.2019.028

Key Words: three-dimensional, dural venous sinuses, drawing

Introduction
Anatomy is a discipline where spatial visualization is of great importance. While textbooks and atlases provide two-dimensional static illustrations, they fall short in exposing three-dimensional dynamics of anatomical structures (Azer and Eizenberg 2007; Berney et al. 2015). As a result, learners may find it difficult to translate two-dimensional images into three-dimensional structures in order to comprehend the dynamic aspects of functional anatomy. Drawing is an effective pedagogical tool that has been used to bridge that transition in anatomy. Drawing is a type of multimedia learning that requires the learner to create original conceptual representations, connecting the new representation with prior knowledge in a generative form of learning (Van Meter and Firetto 2013). Comparisons between creating two-dimensional drawings and three-dimensional drawings or models have shown that students prefer a three-dimensional approach to learning (Estevez et al. 2010; Lisk et al. 2015). By creating three-dimensional models, students also increase their understanding of three-dimensional questions on exams compared to students who just use two-dimensional models. Drawing activities also appeal to many learning styles and they are recommended by students who learn in many different ways (Estevez et al. 2010) during laboratory review, the experimental group constructed 3D color-coded physical models of the periventricular structures, while the control group re-examined 2D brain cross-sections. At the end of the course, 2D and 3D spatial relationships of the brain and preferred learning styles were assessed in both groups. The overall quiz scores for the experimental group were significantly higher than the control group (t(85). Further studies have shown that drawing is an effective way to review material before exams, since it improves student understanding and self-awareness of the course material. This increases student metacognition, their ability to understand their own cognition, and their ability to understand how much of the material they may or may not know (Flavell 1979; Naug et al. 2011).

Drawing is an ideal learning strategy for neuroanatomy given the field’s high visual-spatial demands, as the activity requires students to directly visualize the anatomy and check their understanding at the same time (Ainsworth et al. 2011). Therefore, we developed a novel teaching activity implementing the three-dimensional drawing of dural venous sinuses using swim caps. In particular, we sought to explore if three-dimensional drawing could improve knowledge and understanding of the anatomy and drainage patterns. The three-dimensional visualization of dural venous sinuses is important not only for academic purposes but also as a valuable tool for radiologists, physicians, and neurosurgeons in the diagnosis of various pathologies and surgical interventions in this region.

Method
At the beginning of the session, students were given a pre-test to determine baseline knowledge and a 50-minute lecture on the cranial vault including the dural venous sinuses. Students were assigned to work in pairs and each student was given a plain white swim cap and a blue marker. Students were instructed to put on the swim cap and to draw the dural venous sinuses on their partner’s swim cap using their notes to double check their work. This activity took approximately twelve minutes. While there was no grade associated with the drawing, faculty were present to answer questions and assist...
with accuracy of the drawings. After the drawing activity, students completed an anonymous post-test. Both the pre- and post-test included first and second order questions on the anatomical structure and drainage pathways of the dural sinuses. The post-test also included Likert questions to gather feedback on the overall effectiveness of the activity. The Likert Scale was modified using the following scale: strongly disagree, disagree, agree, or strongly agree. The quantitative data from students' pre- and post-tests were compared using a t-test. Analysis of the Likert data was completed by giving each response a value as follows: 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree. The median and mean values were calculated due to the small sample size. Overall, twelve master's students took part in this activity during their anatomy course. This project was approved by the institutional review board and deemed non-human subjects research, IRB number 19-10-NH-0254.

Results
All participants completed the drawing activity successfully, drawing each of the dural venous sinuses on their partner (Figure 1). Data from the correlating pre- and post-tests showed a significant increase in knowledge as revealed by a 28.3% ($p = 0.017$) increase in the post-test score. As presented in Table 1, students strongly agreed this activity improved their understanding of the dural venous sinus system and found that drawing a three-dimensional image assisted them in their understanding. Students also strongly supported drawing as an effective way to learn anatomical structures and showed high support for wanting more similar hands on exercises as part of the curriculum.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>This exercise improved my understanding of the venous drainage system.</td>
<td>3.67</td>
<td>4</td>
</tr>
<tr>
<td>Translating a 2D picture to a 3D drawing helped me understand the orientation of the sinuses.</td>
<td>3.67</td>
<td>4</td>
</tr>
<tr>
<td>Drawing is an effective way to learn anatomical structures.</td>
<td>3.91</td>
<td>4</td>
</tr>
<tr>
<td>I would like more of these hands on exercises in class.</td>
<td>3.75</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 1: Evaluation of student feedback on activity. Mean and median were calculated from Likert questions using the following scale: strongly disagree = 1, disagree = 2, agree = 3, strongly agree = 4 points.

Discussion:
Due to reduced curricular time and limited access to cadavers, there is a growing trend to develop alternative pedagogical approaches to teach anatomical structures and relationships. While three-dimensional models have been used extensively, they can be costly and lack haptic feedback and interactivity with the learner (Estevez et al. 2010). Therefore, we developed a novel drawing activity using swim caps to visualize and illustrate the dural venous sinuses three-dimensionally. Specifically, the purpose of this study was to evaluate if such a three-dimensional drawing activity assisted students in their understanding of the dural venous sinus anatomy and drainage. Overall, students showed a significant increase in knowledge gained after the drawing activity. Students felt this type of drawing activity was beneficial and enjoyable. They reported that it was an effective way to learn anatomical structures and emphasized the importance of its three-dimensionality to understanding the orientation and drainage of the dural venous sinuses. All students requested that more drawing activities similar to this one be incorporated into their curriculum.
While this is the first reported drawing activity of the dural venous sinuses to our knowledge, similar three-dimensional drawing activities have been utilized to enhance student understanding of anatomical structures. The Anatomy Glove Learning System enables students to learn the hand structure and function by drawing the ligaments and muscles on a worn glove with imprinted bones (Lisk et al. 2015). Researchers found this activity also increased their knowledge of hand anatomy and associated self-confidence. Another study allowed students to either draw a model or create a three-dimensional clay model of the limbs to stimulate active learning and enhance student metacognitive processes (Naug et al. 2011). Body painting has also been used to provide a three-dimensional canvas to learn anatomical structures, facilitate the use of visual cues and color aids, and promote knowledge retention (Finn and Mclachlan 2009).

While the sample size for the data collection was small, we have used this drawing activity with over a hundred students who have all anecdotally enjoyed the activity and found it beneficial to their learning. Because the pre-test was given before the lecture, it is unknown whether students’ overall knowledge improved more from the lecture or from the three-dimensional drawing activity. However, this is a quick and effective pedagogical tool that can be utilized in any anatomy or neuroanatomy class and is applicable to all levels of learners. This activity requires minimal direction and supplies, making this an ideal intervention for small groups or large lab settings.

About the Authors
Jacqueline Shaia received her master’s degree in anatomy from Eastern Virginia Medical School. She is currently a faculty member at Eastern Virginia Medical School in the Department of Pathology and Anatomy where she teaches anatomy, histology and research methods. Her current research includes the use of innovative pedagogical tools such as three-dimensional drawing, interactive e-modules, and virtual reality.

Carrie Elzie is an associate professor in the department of Pathology and Anatomy at Eastern Virginia Medical School and the program director of the Contemporary Human Anatomy Master’s Program. She is currently a Master Educator in the Fine Family Academy of Educators and has been instrumental in developing novel active learning techniques for health professional and medical students.

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A Simple and Effective Way to Teach the Clinical Importance of the Perineal Body

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Abstract
The perineal body is located where four muscles (the superficial anal sphincter, the bulbospongiosus and both superficial transverse perineal muscles) have a common insertion at a nondescript point between the vagina or penile bulb and the anus. Health professions students have difficulty identifying its location and do not have a full appreciation of its function. Clinically, it provides support for the pelvic organs, especially in women. To help clarify the function of the perineal body, a demonstration can be performed which uses three student volunteers and a faculty member. By using one of their hands to represent the perineal muscles, a “perineal body” can be formed. As each person pulls in their respective direction, tension on the “perineal body” is formed; illustrating the concept that the perineal body provides pelvic organ support. During the demonstration, the faculty member discusses the clinical importance of the perineal body. The whole high yield demonstration takes less than two minutes to complete. https://doi.org/10.21692/haps.2019.023

Key Words: perineal body, medical education, gross anatomy, health professions, obstetrics, gynecology

Introduction
The pelvis and perineum are difficult regions to dissect and it is a challenge for health professions students to gain a 3-D appreciation of the organization of this area. This is compounded by the fact the region is also sexually dimorphic. It has been shown that 47% of fourth year Ob/Gyn residents and 40% of Ob/Gyn fellows lack an appropriate understanding of pelvic and perineal neurovasculature, tissue planes, and muscular insertions and origins (Advolodkina and Chahine 2017; Doo et al. 2015). If physicians in advanced OB/Gyn training have difficulty, then health professions students taking an anatomy course for the first time, by extension, would most likely have even greater difficulty comprehending the 3-D aspects of pelvic and perineal anatomy.

Within the perineum, health professions students often find the perineal body to be an enigma that is difficult to conceptualize. Even during dissection on whole or hemisected cadavers, where the perineal body is revealed, it is a somewhat nondescript point. This is frustrating to students who expect to see a clearly defined structure, as it is often shown in anatomy atlases and textbooks (Drake et al. 2015; Netter 2019). Atlases and textbooks typically show the perineal body as a fibrous point of insertion for many of the muscles in the urogenital and anal triangles such as the left and right superficial transverse perineal muscles, the superficial part of the external anal sphincter, and the bulbospongiosus muscle, which is cleft in females (Figure 1) but fused along a midline raphe in males. In reality, the muscles of this region have a complex embryological development which results in variations influencing whether they do, or do not, insert on the perineal body (Peikert et al. 2015; Plochocki et al. 2016; Shafik et al. 2007).

Figure 1. Female perineum with the muscles contributing to the perineal body (asterisk) in bold type. In females, the bulbospongiosus muscle is cleft and surrounds the vaginal vestibule; in males it is fused along a midline raphe. The right and left superficial transverse perineal muscles are found along the posterior edge of the perineal membrane. Image acquired from open knowledge commons use, and slightly modified, from the 1914 Cunningham’s text-book of anatomy.
When asked by an instructor, many students can state which muscles insert on the perineal body and can deliver a rudimentary understanding of the clinical importance of this region. However, it is the author’s experience from over 32 years teaching gross anatomy that few students have a true appreciation and/or understanding for how the perineal body is formed and how it helps to support the pelvic viscera, especially in females. One way to overcome this difficulty in studying perineal anatomy is to use a variety of teaching techniques utilizing the various learning methods preferred by students. Quinn and colleagues (2018) show that the use of active learning combined with sensing, visual, motor, and sequential styles of learning (blended learning) all help to reinforce the ability of students to understand anatomy. For example, visual aids using your fingers, blankets, or movable 3-D models have been used in the past to help teach students cranial nerve functions, abdominal arterial supply, pelvic peritoneal reflections, and knee joint morphology (Cai et al. 2019; Dickson and Stephens 2015; Khalil et al. 2018; Nayak 2006; Oh et al. 2011). Furthermore, having students work in teams or groups has also been proven to be an effective way for students to learn anatomy (Shaffer 2016).

In order to help medical students or health professions students gain a better understanding of the perineal body and its function, the author has developed a simple demonstration utilizing all of the aforementioned learning techniques/styles. This demonstration is a hands-on, team-based method, using sensing, visual, motor, and sequential styles of learning. Since the demonstration is face-to-face, the instructor can gauge student understanding and immediately correct any misconceptions.

**Methods**

The demonstration requires one instructor and three student volunteers. If the demonstration takes place in the gross anatomy laboratory, it is easy to gather three students from one or more neighboring dissection tables to participate. Before the demonstration begins, ask the students to point out the perineal body on a cadaver or pelvic model. Then ask the students which muscles insert on the perineal body. To begin the actual demonstration, have two students stand opposite each other as the east and west compass points to represent the superficial transverse perineal muscles. Each student extends one hand to grasp the hand of the other student (Figure 2). Another student, as the north compass point, extends one hand and grasps the top of other two hands to represent both halves of the bulbospongiosus muscle (Figure 3). Representing the superficial portion of the external anal sphincter, the instructor, as the south compass point, grasps the other three hands from underneath (Figure 3).
As each student extends a hand, the instructor tells each student what muscle he or she represents and that the combined hands are forming a perineal body. While forming the perineal body, it is important that the four individuals be close enough together so their arms are not fully extended. Also inform the students the male bulbospongiosus muscle is in two halves joined at a raphe, while the female bulbospongiosus muscle remains cleft with the posterior aspect of each half inserting on the perineal body (Figure 1).

Once all hands are clasped together, have each person pull in their respective direction. This will cause the newly formed “perineal body” to stiffen. In order to enhance the illusion of how the perineal body helps to support the pelvic organs, the instructor, who represents the superficial external anal sphincter, and has his or her hand underneath the other three, can push slightly upward. When the “perineal body” is stiffened, the instructor then speaks about the clinical importance of how the perineal body is important for preventing pelvic organ prolapse. The entire demonstration can take place in two minutes or less.

Results
Many health professions students come away with a better understanding of how the perineal body functions to support pelvic organs and prevent pelvic organ prolapse. Unsolicited student comments to the instructors, after seeing the demonstration either at the allopathic medical school in Arkansas, or the osteopathic medical school in North Carolina, were positive and expressed how they now had a much better grasp of perineal body formation and its clinical importance. The anatomy faculty at both medical schools noted a reduction in student misconceptions about the anatomy of the perineal region. As further proof of the usefulness of this demonstration, students who have participated in the demonstration often show it to their peers along with discussing its clinical relevance.

Discussion
This is a simple, effective way to show how the perineal body is formed and functions. Although the students may be initially reticent to participate, it does not take much cajoling to have them volunteer, especially if you tell them it will be “high yield”. Using this phrase catches the attention of students, since they themselves use it to describe basic science content they feel is essential to learn for national board exams such as the allopathic USMLE or the osteopathic COMLEX exams. Another way the demonstration can be memorable, is to make sure the instructor always represents the external anal sphincter. Not only does this avoid inferring one of the students is a “less than desirable” part of the anatomy, it has never failed to elicit laughter for the 27 years the author has been doing this demonstration when you say, “I know no student wants to be the external anal sphincter, so that’s always me.” The author has had students who are no longer in the gross anatomy course come back and ask if the perineal body demonstrations are still being used. This attests to the positive impact this simple demonstration has made on health professions students to help them remember the clinical importance of the perineal body.

In order to impart the clinical importance of the perineal body, several examples can be mentioned after the physical aspect of the demonstration is over. Emphasizing the importance of keeping the perineal body intact during labor and delivery for the prevention of pelvic organ prolapse and incontinence is essential (Plochocki et al. 2016; Woodman and Graney 2002). Information concerning the placement of an episiotomy in order to prevent an uncontrolled laceration through the perineal body (potentially into the anorectal junction), and which structures are cut via a midline vs. a mediolateral incision, needs to be included in the discussion (Table 2 Woodman and Graney 2002). At the same time, the students can be informed that stretching of the perineal body, which occurs normally during labor, does not impair the function of the perineal body regarding pelvic organ support or incontinence (Meriwether et al. 2016). Concerning males, the importance of keeping the anatomy of the perineal body intact during prostate or anorectal surgery in order to help avoid impotence and incontinence can be mentioned (Kraison et al. 2015).

Conclusion
In conclusion, descriptions of the anatomy of the anal and urogenital triangles in most texts and atlases show the “classic” relationship of the perineal muscles with the perineal body; however, these are inaccurate (Drake et al. 2015; Netter 2019). Nevertheless, although they may be inaccurate, this does not detract from the clinical relevance of this structure, regardless of how many of the perineal muscles do, or do not, directly insert on the perineal body (Kraison et al. 2015; Plochocki et al. 2016; Shafik et al. 2007). Considering an undergraduate medical education should be generalized (we are not teaching the students to be anatomists or surgeons), the anatomy atlas or text that shows a classical representation of the perineal body and the muscles that “insert” into it suffices. The detailed specifics of the perineal musculature and their variations, insertions and neurovasculature can be learned during postgraduate training such as during Ob/Gyn, urology or other pertinent surgical residencies.

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A Simple and Effective Way to Teach the Clinical Importance of the Perineal Body

Usefulness to Anatomy and Physiology Instructors
This brief demonstration is easy to learn and it can be performed in less than two minutes. It illustrates to health professions students how the perineal body is formed and its importance in supporting pelvic organs, especially in women. The demonstration can be performed in a gross anatomy laboratory setting as well as in a lecture hall. It has proved to be effective in the education of medical, physician assistant, physical therapy and graduate students.

Acknowledgements
I thank my Anatomy Department colleagues for their “helping hands”. This was presented in abstract form at the 2019 Annual Meeting of the International Association of Medical Science Educators (IAMSE) in Roanoke, VA.

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Case Studies in The Instruction of Human Anatomy and Physiology

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Abstract
Case studies are an effective way to increase engagement of students in learning complex concepts in Human Anatomy and Physiology. This collaborative manuscript highlights the use of case studies, as well as provides several examples of different styles of case studies that can be used. The case studies presented cover topics relevant for reproductive, respiratory, and endocrine system discussions. Cases are presented with questions and suggested answers, as well as a link to the relevant 2019 Fall HAPS Anatomy and Physiology Learning Outcomes. https://doi.org/10.21692/haps.2019.026

Key Words: case studies, anatomy and physiology, education, active learning strategies, endocrine, physiology, respiratory physiology

Introduction
Science and mathematics education in the United States is deemed to have fallen behind other nations (Herreid 2007). This is considered a fundamental issue and “schools around the nation are seeking curriculum reform and classroom innovations to aid in rectifying the deficiency in scientific literacy” (Herreid 2007).

When case studies were initially used in classrooms, they were used as a mere storyline for general information or historical data, not necessarily as a teaching method. Although they were used in other disciplines (e.g. law and business schools, medicine, and physiology), case studies were not considered pedagogical tools for the fields of science and mathematics (Herreid 2007). Case studies are now used widely in anatomy and physiology and basic science education primarily to prompt students to explore content and evaluate data (Cheek et al. 2018).

Active learning strategies, such as case studies, create a more engaging environment in the classroom and have a positive impact on retention (Lorenzo-Alvarez et al. 2019). Using case studies, students can become enticed with scenarios to solve problems as detectives do, using deductive rather than inductive reasoning. Students assess facts and analyze the problems faced in the story (Herreid 2007). In this way, the goal of using case studies becomes two-fold: (1) to teach science and mathematics skills in a unique manner, and

(2) to “develop higher-order skills of learning” (Lundeberg et al. 1999; Herreid 2007). Activities that require critical thinking and reflection encourage deeper level thinking and foster metacognition (Joshua 2017). The development of metacognition further assists students in their learning as they begin to self-monitor their own study techniques (Tang and Chow 2019). In addition to knowledge retention and improved critical thinking skills, case studies bring a real-world aspect to content that may otherwise seem abstract to students. Case studies are relatable and provide the opportunity to foster compassion and empathy in nursing and medical students (Gregory et al. 2015)

In that regard, there are three types of case studies that can be adopted, depending on the pedagogical goal (Herreid 2007):

1. Decision or Dilemma Case studies:
The theme involves a central character in a drama that is used and who must solve a problem or make a decision based on a storyline.

2. Appraisal or Issue Case studies:
The theme is one of teaching critical thinking and answering questions such as “What is going on here?”

3. Case History Case studies:
The theme is one of illustrating science in action, such as looking at phenomena of the past and how it was handled.

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Case studies can be taught in the following ways (Herreid 2007):

1. **Problem-based learning format:**
   Often used in medical schools. Students are presented with real-life and practical questions regarding patients within their field of domain, i.e., pediatrics, geriatrics, etc., and the case goes through several stages of discussion and reflection with assistance from the teacher along the way.

2. **Scientific Research Team format:**
   Students sift through a plethora of information on a topic and must answer problems, develop questions, or address dilemmas.

3. **Team learning format:**
   Students form small collaborative groups and deal with a problem together.

4. **Discussion format:**
   Often used in business and law schools, students are presented with a case and are required to understand the issues being faced, possible solutions and consequences.

5. **Debate format:**
   Often used in law schools, students discuss “diametrically opposed views.”

6. **Public Hearing format:**
   Students form a panel and listen to a variety of viewpoints regarding a scenario.

7. **Trial format:**
   Similar to debate format, and often used in law schools, students form an opposing party in a law case (plaintiff and defendant), and a judge, and discuss the opposing sides while the judges rule a decision.

This article aims to increase the knowledge of case studies for use in the classroom and to address one of the top obstacles reported by faculty nationwide regarding the use of case studies in their classroom, which is the lack of relevant/useful case studies (Yadav and Lundeberg 2006). The study by Yadav and Lundeberg (2006) showed that 60% of faculty surveyed reported this particular issue as an obstacle for using case-based learning in the classroom. Cases presented in this article cover topics which address topics less commonly found in existing case studies including acromegaly, post-partum lactation, and gas exchange at the International Space Station (ISS), and Amyotrophic Lateral Sclerosis. Each case has an introduction that explains how it has been used and the type of case study it is. Suggested discussion questions are linked to relevant HAPS Learning Outcomes (HAPS 2019), and suggested answers follow each question.

**About the Authors**

During the HAPS Annual Conference in Oregon these individuals attended the Writing Squares Workshop and collaborated on the idea of writing case studies that could be used in Anatomy and Physiology classes. Each author contributed to the article by writing case studies that linked to HAPS Learning Outcomes for Anatomy and Physiology and the introduction on why use of Case Studies can enhance teaching effectiveness.

**Literature cited:**


Human Anatomy and Physiology Society Anatomy and Physiology Learning Outcomes, Revised Fall 2019.


Case Study Example A:

Pituitary Adenoma and Acromegaly
This case study was designed for undergraduate students that are taking the second half of anatomy and physiology. Prior to doing the case study students will have been exposed to negative feedback and homeostatic regulation by the endocrine system. This case study has been used by the author as an online assignment and in a discussion class where students work in small groups. Typically, students will already have knowledge of the brain and the anatomy of the skull which can allow instructors to also use this case study to discuss complications of a pituitary adenoma in the cavernous sinus. Usually this case study takes students about 45 minutes to complete with instructor support. For many students it is a good way for them to review the hypophyseal portal system and the interaction between the hypothalamus and adenohypophysis.

Tyler Sullivan is a 38-year-old man who has been experiencing joint pain, headaches, and visual disturbances. Tyler makes an appointment to see his doctor who examines him and asks him how frequently he is experiencing these symptoms. While discussing his symptoms, Tyler mentions that his daughter is getting married and he wants to feel good for the wedding. He tells the doctor his wife and he were looking at photographs from their own wedding 18 years ago and it became obvious to him that his appearance has changed. He explains that his brow and jaw appear to look more protruding and recently noticed that his hands seem larger because his wedding ring is tight.

Following his physical exam Tyler’s doctor was suspicious of a hormonal imbalance and recommended that tests be ordered to evaluate his condition. These tests confirmed elevated growth hormone (GH), elevated insulin-like growth factor (IGF-1) and elevated blood glucose following a growth hormone suppression test. As a follow up a magnetic resonance imaging (MRI) test was ordered. The MRI identified a tumor on his pituitary gland. Together these tests indicate that Tyler has Acromegaly which if left untreated can result in major health problems.

Based on this case study please answer the following questions:
1. GH is a major hormone secreted by the anterior pituitary gland. What is the function of this hormone? How does it increase blood glucose levels?
2. Where is the pituitary gland located in the body?
3. How is GH released and controlled by negative feedback?
4. What is a growth hormone suppression test and what is indicated by elevated glucose levels following the test?
5. Why are levels of GH, glucose and IGF-1 elevated? How is this treated with medication or with surgery?
6. What are the potential serious health issues that patients can experience if elevated GH persists?

Case Study A Answers:
1. Growth hormone is a major hormone secreted by the anterior pituitary gland. What is the function of this hormone? How does it increase blood glucose levels?

HAPS Anatomy and Physiology Learning Outcome:
Module J: Endocrine System
8. Application of Homeostatic Mechanism
Describe examples of how the endocrine organs interact with other body organs and systems to maintain homeostasis.

GH is secreted by the anterior pituitary gland and stimulates cell growth (reproduction and regeneration) in all cells of the body but has its greatest effect on cartilage, bone and muscle. GH stimulates liver cells to release (IGFs) (somatomedins), which binds to a variety of cells. Following meals IGFs increase the absorption of amino acids by cells to accelerate protein synthesis making elevated levels of blood glucose available to produce ATP through aerobic metabolism.

GH has a glucose sparing effect on adipose tissue where it stimulates the breakdown and release of fatty acids from adipose tissue and prompts peripheral tissues of the body to utilize these fatty acids instead of utilizing the glucose in the blood. GH also stimulates the breakdown of glycogen from liver cells. This, combined with the utilization of fatty acids to produce ATP rather than glucose, can lead to an increase in blood glucose levels (diabetogenic effect).
2. Where is the pituitary gland located in the body?
The pituitary gland lies within a depression of the sphenoid bone called the sella turcica.

3. How is GH released and controlled by negative feedback?

HAPS Anatomy and Physiology Learning Outcome:
Module J: Endocrine System
4. Endocrine Control by the Hypothalamus and Anterior Pituitary Gland
   Describe locations and anatomical relationships of the hypothalamus and anterior pituitary gland, including hypothalamic-hypophyseal portal system.

Growth hormone releasing hormone (GHRH) is a hypothalamic peptide that stimulates the secretion of GH by the anterior pituitary gland. Growth hormone secretion targets the liver and stimulates the release of IGF-1. High blood levels of IGF-1 lead to a decreased secretion of growth hormone by suppressing growth hormone releasing hormone and by stimulating the release of somatostatin, also known as growth hormone inhibiting hormone (GHIH), from the hypothalamus. In normal individuals rising levels of blood glucose should decrease GH secretion by the anterior pituitary gland.

4. What is a growth hormone suppression test and what is indicated by elevated glucose levels following the test?

HAPS Anatomy and Physiology Learning Outcome:
Module J: Endocrine System
9. Prediction related to disturbance in homeostasis
   1. Given a factor or situation predict changes that occur in the endocrine system and the consequences of those changes.

First the patient is fasted, and blood tests are taken over a period. The first sample is collected between 6:00am and 8:00am, before eating or drinking. The patient is then asked to drink a beverage containing 75 grams glucose in five minutes. The next blood tests are taken at 30-minute intervals for two hours. Because GH participates in negative feedback with IGF-1, rising levels of IGF-1 should decrease levels of GH. If the GH levels do not change and stay high during suppression testing this may indicate gigantism or acromegaly.

5. Why are levels of GH, glucose and IGF-1 elevated? How is this treated with medication or with surgery?

HAPS Anatomy and Physiology Learning Outcome:
Module J: Endocrine System
9. Prediction related to disturbance in homeostasis
   2. Given a disruption in the structure or function of the endocrine system predict the possible factors or situations that might have caused that disruption (i.e., given an effect, predict possible causes).

The MRI indicates Tyler has a pituitary tumor and although this is a benign tumor, it is hypersecreting GH so that rising levels of IGF-1 continue and do not decrease the section of GH. Medications can be used to try to control GH to decrease the secretion of IGF-1 by the liver. These medications mimic GHIH (somatostatin).

Where surgery is indicated an endonasal endoscopic procedure can remove the tumor through the nostrils. The surgeon will access the tumor through the nostrils, open the sphenoid sinus and open the base of the skull to reach the tumor. Using endoscopic tools and a 3D image of the brain on a monitor, the tumor is removed. The skull base is then sealed off following surgery to prevent leaking of cerebrospinal fluid. Following surgery radiation may be required to remove any tissue left behind.
6. What are the potential serious health issues that patients can experience if elevated GH persists?

   **HAPS Anatomy and Physiology Learning Outcome:**
   **Module J: Endocrine System**
   9. Prediction related to disturbance in homeostasis
   1. Given a factor or situation predict changes that occur in the endocrine system and the consequences of those changes.

Persistent elevation of GH and IGF-1 leads to abnormal blood glucose regulation that can increase the incidence of diabetes mellitus, hypertension and heart disease. These increased levels have also been associated with higher risk of colon and thyroid cancer.

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**Case Study Example B:**

**A Case Study of Laine Callahan: Establishment and Maintenance of Lactation**

This case is designed to be an example of an appraisal or issue case used in a two-semester undergraduate Anatomy and Physiology course, an upper division undergraduate Human Physiology course, or a graduate level Physiology course. With some modifications and additions, the case can be adapted to fit into a Problem-Based learning curriculum. The case has been delivered as a homework assignment for an online-only 2nd semester Human Anatomy and Physiology undergraduate course but would work well as an in-class group assignment for small group discussion. The case was used to review concepts that had been previously covered in class through lecture. It could also be used to introduce a topic to the class, if an appropriate reading assignment was given beforehand to cover pregnancy, lactation, and the female reproductive system.

**Part 1:** Laine Callahan is a 30-year-old insurance salesperson who works from home. She is single and has just delivered her firstborn daughter, Topanga, through a fast and pain-medication-free vaginal delivery. She has been looking forward to this day when she would meet her daughter since she first began the journey of in vitro fertilization almost two years ago. Throughout the last nine months, Laine read a lot about breastfeeding and how beneficial it is for both baby and mom and how her body prepared for lactation while she has been pregnant. From her reading, Laine found that early skin to skin contact between mother and child, along with the immediate introduction of the breast for feeding, often lead to greater success with breastfeeding.

With the help of Nurse Jessica, breastfeeding was successfully attempted for Laine and Topanga. Laine was instructed to keep track of which breast Topanga nursed from and for how long. She was also instructed to keep track of wet and dirty diapers to help ensure that Topanga is getting enough to eat/drink. After the first 20-minute nursing session, Topanga was taken for routine tests.

Topanga frequently nursed for the rest of the day. She produced eight wet and two soiled diapers over 24 hours.

**Questions for deeper inquiry/discussion:**

1. **How does the mother’s body prepare for lactation during the final days of gestation and postpartum?**
   Explain how this hormonal shift regulates lactation.
2. **What are the other hormonal changes that occur in a postpartum mother who is lactating?**
3. **What is the “first milk” composed of and how is it different from the milk Laine will make in 3-5 days?**

**Part 2:** During the night, Laine became concerned with how frequently Topanga was nursing and expressed her concern to Nurse Jessica that she may not be producing enough milk. Nurse Jessica explained that the colostrum she was producing is enough for Topanga and reminded Laine that her milk would “come in” within the next couple days if she and Topanga continue to nurse frequently. In addition to her fear of not producing enough milk, Laine complains that she has been feeling intense uterine cramping when Topanga nurses which Jessica explains is not unexpected in a nursing mom.

Two days later, Laine and Topanga are given permission to go home.

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*continued on next page*
Questions for deeper inquiry/discussion:
1. What is meant by the milk “coming in”?
2. How does milk production change over time for the mother?
3. Explain the milk ejection reflex.
4. Why is Laine experiencing uterine cramping when Topanga nurses?

Case Study B Answers:
1. How does the mother’s body prepare for lactation during the final days of gestation and postpartum? Explain how this hormonal shift regulates lactation.

HAPS Anatomy and Physiology Learning Outcome:
Module R: Reproduction
11. Postpartum changes to the mother
4. Describe the hormonal regulation of lactation.

During gestation, the high levels of progesterone and estrogen help to initiate the development of the mammary glands to support milk production postpartum. The high levels of placental progesterone cause the release of prolactin inhibiting hormones from the hypothalamus which will inhibit the release of prolactin and as a result hinder lactation. Towards the end of pregnancy, there is a rise in placental estrogen and human placental lactogen which stimulates the release of prolactin-releasing factors from the hypothalamus. This leads to the production of colostrum.

2. What is the postpartum period and what are the other hormonal changes that occur in a postpartum mother who is lactating?

HAPS Anatomy and Physiology Learning Outcome:
Module R: Reproduction
11. Postpartum changes to the mother
1. *Define the postpartum period.
2. *Describe the hormonal changes that occur after parturition.

The postpartum period lasts from approximately six to eight weeks after delivery. This is when the mother’s body returns physiologically to the non-pregnant state. Without the placenta, levels of progesterone and estrogen rapidly decrease. In lactating women, follicle stimulating hormone (FSH) levels return to normal levels, but luteinizing hormone (LH), estrogen, and progesterone levels remain low with exclusive breastfeeding (McNeilly 1979).

3. What is the “first milk” composed of and how is it different from the milk Laine will make in 3-5 days? The first milk is called colostrum. Colostrum, also referred to as “liquid gold”, is a thin, low fat secretion that has a very high percentage of antibodies that are important for providing some initial passive immunity to the neonate. It contains lactoferrin, leukocytes, epidermal growth factor, and IgA (Ballard and Morrow 2013). Additionally, it contains high levels of sodium, chloride, and magnesium in comparison to the later milk (Ballard and Morrow 2013). Colostrum obtains lower levels of lactose than later human milk, which supports the role of colostrum in providing immunity and trophic factors over nutrition (Ballard and Morrow 2013).

4. What is meant by the milk “coming in”? The composition and quantity of milk changes at two to three days postpartum to more closely resemble milk. The reason for this change is the dramatic decrease in progesterone that occurs after the delivery of the placenta.

5. How does milk production change over time for the mother?

HAPS Anatomy and Physiology Learning Outcome:
Module R: Reproduction
11. Postpartum changes to the mother
4. Describe the hormonal regulation of lactation.
Milk production immediately following birth relies on the hormonal changes from the delivery of the placenta and decrease in progesterone, along with increased prolactin release. To maintain milk production several days after birth, mechanical stimulation is required. During this time, prolactin secretion slows and for milk to continue to be produced, the nipple must be stimulated. The hormonal cascade from mechanical stimulation is based on the release of prolactin releasing factors, which release prolactin and lead to milk production.

6. Explain the milk ejection reflex.

**HAPS Anatomy and Physiology Learning Outcome:**
Module R: Reproduction
11. Postpartum changes to the mother
4. Describe the hormonal regulation of lactation.

Suckling of the nipple leads to the release of oxytocin. Oxytocin causes contractions of the myoepithelial cells of the milk ducts which leads to milk being ejected from the ducts through the nipples.

7. Why is Laine experiencing uterine cramping when Topanga nurses?
With the suckling of the nipple, oxytocin release is initiated. Oxytocin has effects on the uterus and causes continued contractions of the myometrium in addition to its effects on the myoepithelial cells of the breast.

**Literature cited:**


**Additional Resources:**


**Case Study Example C:**

A Case Study of Elevated CO2 Levels on the International Space Station (ISS)
This case is designed to be used in a two-semester undergraduate Anatomy and Physiology course, an upper division undergraduate Human Physiology course, or a graduate level Physiology course. With some modifications and additions, the case can be adapted to fit into a Problem-Based learning curriculum. The case has been delivered as a in-class small group activity in a 2nd semester Human Anatomy and Physiology undergraduate course but would work well as an online class group assignment for small group discussion.

Part 1: When astronaut Scott Kelly finished a long day of work aboard the International Space Station (ISS), he often finished his day by video calling his girlfriend Amiko Kauderer. Amiko would often notice Scott was irritable during their nightly conversations. This was not a new symptom for Scott, and Amiko had learned that when Scott was irritable, the Carbon Dioxide (CO₂) levels within the ISS were likely high. High CO₂ was a common complaint for Scott, and even his girlfriend could recognize the symptoms of high CO₂ while she was comfortably back on Earth.

Questions for deeper inquiry/discussion:
1. Recall that CO₂ is carried in the blood in three ways. How much is typically carried as a dissolved Gas in plasma? How much is typically bound to Hemoglobin inside Red Blood cells? And how much will undergo the following equation: CO₂ + H₂O ↔H₂CO₃ ↔H⁺ + HCO₃⁻?
2. Where does the conversion of CO₂ and H₂O occur? What critical enzyme is present to facilitate this chemical reaction?
Part 2: On Earth, the typical level of CO₂ in the atmosphere is less than 1% with outside air typically containing .04% CO₂ levels. Inside closed rooms or buildings, a typical indoor CO₂ concentration is between 0.8% and 1%, and previous studies have shown that there are no negative physiological effects of CO₂ concentrations below 1%. It is believed that several hours of exposure to 2% CO₂ is necessary before headaches or other symptoms would occur in individuals on earth. The maximum allowable CO₂ concentration on the ISS considered safe was set for 0.8% CO₂ of ISS air. ISS astronauts are briefed that symptoms associated with high levels of CO₂ could result in headaches, dyspnea, irritability, dizziness, increased blood pressure, and burning in the eyes and sinuses, along with changes in mood.

Question for deeper inquiry/discussion:
1. Explain how raised CO₂ levels in the atmosphere or air could lead to less CO₂ removal and how this could link to respiratory acidosis occurring?

Part 3: The body will detect increased CO₂ levels via peripheral chemoreceptors in the carotid and aortic arch areas and central chemoreceptors in the medulla oblongata. The central chemoreceptor, upon sensing higher concentrations of H+ ions in the Cerebral Spinal Fluid (CSF), triggers an increase in breathing rate (hyperventilation) and breath volume (tidal volume) to expel more CO₂.

Question for deeper inquiry/discussion:
1. How does the central chemoreceptor sense hydrogen ions in the CSF and correlate that to rising carbon dioxide levels?

Part 4: The peripheral chemoreceptors are sensitive to CO₂, hydrogen ion, and oxygen within the blood. When they detect increased CO₂ or hydrogen ion levels (leading to decreased pH), the receptors send a signal to the medulla oblongata, which should trigger increased rate and depth of breathing, leading to more expulsion of CO₂ during respiration.

On the ISS, which is a closed system, there are two CO₂ scrubbers called the Carbon Dioxide Removal Assemble (CDRA), which are designed to reduce CO₂ levels. These devices are set to turn on when the CO₂ concentration on the ISS reaches ~0.8%. Usually only 1 CDRA is being used at a time while the second unit is the “back-up”. However, astronauts are experiencing symptoms of high CO₂ levels below the 0.8% level. Kelly noticed that once CO₂ levels on the ISS reached 0.4%, ten times greater than terrestrial levels, he experienced headaches and sinus congestion. As CO₂ concentrations rose above 0.5%, Kelly self observed degraded cognitive abilities and a felt burning sensation in his eyes. His irritability appeared to worsen as CO₂ increased on the ISS.

Question for deeper inquiry/discussion:
1. Propose a hypothesis for why astronauts might be experiencing symptoms aboard the ISS of High Carbon Dioxide levels that are below the typical threshold of 1% on Earth when these symptoms present?

Part 5: The evidence points to the human body in microgravity and a closed system appears to have lower tolerance to CO₂ levels compared to Earth. While the CDRA is capable of reducing CO₂ levels, it is a loud piece of equipment when operating and prone to breakdowns and new ideas might be necessary to provide a solution for CO₂ removal from the breathing air aboard future spacecraft.

Question for deeper inquiry/discussion:
1. What implications might this have for future space voyages to Mars and for establishing colonies or other long-term living facilities on the Moon and other planets?

Case Study C Answers:
1. Recall that CO₂ is carried in the blood in three ways. How much is typically carried as a dissolved gas in plasma? How much is typically bound to Hemoglobin inside Red Blood cells? And how much will undergo the following equation: \( \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \)?

HAPS Anatomy and Physiology Learning Outcomes
Module M: Respiratory System
6. Mechanisms of gas transport in the blood
8. Describe the ways in which carbon dioxide is transported in blood and explain the relative importance of each to total carbon dioxide transport.
9. State the reversible chemical equation for the reaction of carbon dioxide and water to carbonic acid and then to hydrogen ion and bicarbonate ion.
The concentration of dissolved CO₂ gas is a function of Henry’s Law and under normal atmospheric conditions only about 7% will be dissolved in the plasma. Approximately 23% of the CO₂ carried by blood is bound to the protein portions of hemoglobin molecules within red blood cells. These CO₂ molecules are attached to exposed amino groups (-NH₂) with the hemoglobin protein structure. Roughly 70% of the CO₂ is transported to the lungs by the carbonic anhydrase enzyme presence and chemical reaction of carbon dioxide and water to hydrogen ions and bicarbonate. The bicarbonate ions move into the plasma with the aid of a counter-transport mechanism that exchanges plasma chloride ions (Cl⁻) for intracellular bicarbonate ions. This allows one anion to trade for another and does not require ATP. It also results in a mass movement of chloride ions into the red blood cell which is an event known as the chloride shift.

2. Where does the conversion of CO₂ and H₂O occur? What critical enzyme is present to facilitate this chemical reaction?

HAPS Anatomy and Physiology Learning Outcomes
Module M: Respiratory System
6. Mechanisms of gas transport in the blood
8. Describe the ways in which carbon dioxide is transported in blood and explain the relative importance of each to total carbon dioxide transport.
14. Explain the role of each of the following in carbon dioxide transport: carbonic anhydrase, hydrogen ions binding to hemoglobin, the chloride shift, and oxygen-hemoglobin saturation level.

Conversion of carbon dioxide and water occurs with red blood cells because that is where enzyme carbonic anhydrase is located.

3. Explain how raised CO₂ levels in the atmosphere or air could lead to less CO₂ removal and how that translates to respiratory acidosis?

HAPS Anatomy and Physiology Learning Outcomes
Module M: Respiratory System
6. Mechanisms of gas transport in the blood
10. Explain the relationship between pH and hydrogen ion concentration.
11. Predict how changing the partial pressure of carbon dioxide will affect the pH and the concentration of bicarbonate ions in the plasma.

Gas diffusion is based upon gradients that exist. As the amount of CO₂ in the outside air or atmosphere increases, the diffusion gradient for CO₂ to leave the blood and enter the alveoli and ultimately air decreases. With roughly 70% of CO₂ being carried in the blood as bicarbonate ions, if less CO₂ is removed from the respiratory system, potentially more bicarbonate and hydrogen ions will then remain in the blood stream. As the body continues to produce more CO₂, this decrease in CO₂ loss at the lungs could translate in more hydrogen ions accumulating in the blood stream leading to a decrease in pH creating acidic conditions.

4. How does the central chemoreceptor sense hydrogen ions in the CSF and correlate that to rising CO₂ levels?

HAPS Anatomy and Physiology Learning Outcomes
Module M: Respiratory System
6. Control of Pulmonary Ventilation
2. List and describe the major chemical and neural stimuli to the respiratory centers.
3. Compare and contrast the central and peripheral chemoreceptors

As the Partial Pressure of CO₂ in the arterial blood increases, a condition known as hypercapnia, more CO₂ cross the blood brain barrier and raise the Partial Pressure of CO₂ within the CSF. In the CSF, higher amounts of CO₂ combine with water forming carbonic acid which quickly dissociates into hydrogen ions and bicarbonate ions. This leads to CSF pH becoming more acidic and triggering the chemoreceptive neurons of the medulla oblongata to increase the rate and depth of respiration.

5. Propose a hypothesis for why astronauts might be experiencing symptoms aboard the ISS of high CO₂ levels that are below the typical threshold of 1% on Earth when these symptoms present?

continued on next page
HAPS Anatomy and Physiology Learning Outcomes
Module M: Respiratory System
1. Given a factor or situation, predict the changes that could occur in the respiratory system and the consequences of those changes.

The answer could be a variety of things, unknown at this time but microgravity, adaptations to the chemoreceptors are all possible hypotheses.

6. What implications might this have for future space voyages to Mars and for establishing colonies or other long-term living facilities on the Moon and other planets?

HAPS Anatomy and Physiology Learning Outcomes
Module M: Respiratory System
1. Given a factor or situation, predict the changes that could occur in the respiratory system and the consequences of those changes.

The answer is open for students and instructors to speculate.

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Spring 2020

Clinical Correlates in Physiology
(1 credit) February 4 - 25, 2020
Patrick Eggena, M.D.
Novateur Medmedia, LLC

View Syllabus

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This course supplements the physiology of the heart, lung, and kidneys taught to pre-medical and nursing students by HAPS professors. In this course students are asked to put themselves in the role of a country doctor who is solving practical medical problems using this knowledge. This course reviews, integrates, and applies these basic principles in physiology. The philosophy of this course is that graphic essays are easier to grade than written essays and are better indicators of integration of knowledge than multiple choice exams. Therefore, in this course, exams are structured so that questions are answered primarily with graphs and drawings. In his weekly discussions, Dr. Eggena demonstrates with sketches, block diagrams, graphs, and equations how to answer essay questions in physiology. The students learn to visualize the problems and how to explain complex physiological processes in graphic form. A pool of 16 questions concerning the most important physiological topics is listed in the syllabus. Students practice for the exam by drawing answers to all 16 questions. Any four of these questions are then chosen by Dr. Eggena for a 2 hour proctored graphic essay exam.
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This committee develops standards for laboratory safety. The committee maintains a variety of safety documents available for download.

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Valerie O'Loughlin
Dee Silverthorn
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