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Student Perception of How to Succeed in a Pre-Nursing Anatomy and Physiology Course

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Abstract
Many university students begin the pre-nursing anatomy and physiology course unprepared for the pace and intensity. In a voluntary writing activity on the last day of the two-semester anatomy and physiology class, students were asked to write a letter to the next year’s students to offer advice on how to pass the course, no further direction or guidance of what to write was provided. Data consisted of 283 open letters containing each student’s voice, broken down into in vivo codes. Several themes emerged from the codes. Essays recognized the value of study and learning skills, while also voicing negative affective feelings towards the anatomy and physiology course, suggesting that many students were unprepared for this college level course. This study informs anatomy instructors of student preparation and attitude toward an anatomy and physiology course.

https://doi.org/10.21692/haps.2020.014

Key words: Anatomy and Physiology, pre-nursing, college readiness, study skills, STEM

Introduction
First year students who major in Science, Technology, Engineering or Mathematics (STEM), pre-med or pre-nursing programs, generally enter school with optimism and a feeling of self-confidence, and yet many students flounder during their first college level biology, chemistry, or physics courses (Mayner et al. 2013; Owens 2020; Sooun and Xiang 2008). Gwazdauskas et al. (2014) examined factors that affected student success in an anatomy and physiology (anatomy/physiology) program. Female biology majors earned the highest grades and non-majors scored the lowest grades. The investigators advocated that high school advanced placement biology courses need to better prepare students for a college level anatomy/physiology course. Half the students who took the 2004 ACT exam were not prepared for or capable of reading college level texts or literature, and less than half were prepared to take college level science courses (Lewin 2005). Colleges assume students are prepared for college level work. Students often lack knowledge of how to develop learning skills and supportive positive attitudes towards learning (Bosley 2008; Ding and Mollohan 2015; Hammer and Elby 2003; Kamenetz 2016; Moore and Rubio 2012; Wischusen et al. 2010; Wheeler and Wischusen 2014).

Anatomy/physiology courses by definition consist of intense, fast-paced lessons, requiring student dedication, time management, and honed study skills. Previous research has explored student preparedness for college-level anatomy/physiology courses by examining students’ high school education, specific high school courses taken, high school GPA, and standardized test scores (Harris et al. 2004; House 2000; McKee 2002; Sadler and Tai 2001). Some studies explored university created models to evaluate program candidates (Stankus et al. 2019). However, there is a lack of understanding concerning what methods promote or correlate with success and failure of students specifically taking anatomy/physiology courses (Harris et al. 2004).

Green et al. (2009) described how entrance exam scores and high school performance could predict success in a college level physiology course. However college level anatomy/physiology courses required a unique set of learning skills and could not be predicted in this study. Harris et al. (2004) showed a correlation between the number of previous mathematics and science courses a student has taken and success in an anatomy/physiology course. Burns and Garrett (2015) examined preadmission variables such as grade point average and Medical College Admissions Test (MCAT) scores as predictors for success in a medical program, and found correlation between success and the MCAT microscopic anatomy results. Davis et al. (2018) observed that college health professional programs focused on prospective students with high grade point averages and high test scores, but some of those students struggled in college due to a variety of reasons, including burnout, lack of motivation, lack of interest, and lack of preparation (Hidi and Harackiewicz 2000).

Casual conversation among anatomy/physiology instructors at a recent conference revealed that student success and retention is problematic among freshmen anatomy/physiology students in pre-nursing and ancillary health programs at numerous universities. Yet, minimal literature is available that explores student preparedness for college level...
pre-nursing entry courses, or student withdrawal from college level pre-nursing programs (Mitchell 2012).
A high school diploma does not guarantee success at a four-year college. Only 56% of high school graduates manage to earn a college degree in 6 years (ACT 2010). Half to two-thirds of all high school graduates are unprepared for college and struggle to succeed in college (Balfanz 2009; Greene and Forster 2003). Colleges expect college-bound high school students to graduate with a foundation of reading comprehension, writing, and mathematics skills (Fletcher and Tienda 2009b). College faculty identified writing skills and research skills to be critical for student success (Conley 2003), but Conley (2014) identified additional factors that equally impacted first year college student success, such as development of interest and curiosity, development of time management and life skills, and insight to choose the correct college.

Adelman (2006) explained that successful new college students mastered the content and skills of their high school classes, while students who did not master content or skills often needed to take remedial courses and were less likely to earn a college degree. Evidence showed that only 30% of students requiring just one remedial reading course would earn a college degree in eight years (Adelman 2006).

“A lack of mastery in math, writing, and especially reading skills seems to be an especially powerful indicator of un-readiness for college, no matter how many core courses the given student passed in high school” (Adelman 2006, p. 25).

Kanmetz (2016) explained that the national high school graduation rate is 82%, yet less than 40% of high school graduating students tested college and career ready on the National Assessment of Educational Progress (NAEP), which suggests that 40% of the graduating students were not prepared to succeed in college.

In this study, rather than trying to determine the factors predicting student success in an anatomy/physiology course, we examined student perception of what was necessary to succeed in our two-semester anatomy/physiology course, which is intended for pre-nursing and ancillary health majors. The primary research question was: From the point of view of students completing a two-semester anatomy/physiology course, what skills did the students perceive as important or necessary in order to pass the course? Secondary questions included: What gaps in pre-college preparation for the course were identified? How did the students perceive the course?

Methodology
Sampling and participants
This study took place at a Mideastern research level 1 university that offers a wide range of majors in the sciences and medical fields and, concerning this study, a popular four-year Bachelor’s in Science degree in Nursing (BSN). Included in this study, in minimal numbers, were students aiming for BS degrees in nutrition, public health, and family services. All these majors required a two-semester anatomy/physiology course, which consisted of 2.5 hours of lecture and 1.9 hours of lab per week. At the beginning of the first semester, 2014 and 2015 respectively, there were 292 and 288 students registered on the class roster. At the end of the two-semester course, only 157 (54%) and 163 (57%) students remained on the roster.

The last week of class during the second semester, students celebrated their completion of the course. Conversation lead to why they were successful while roughly half of those who started the course failed or dropped out. Discussion turned into opportunity, and interested students were invited to write a one-page letter to the future students who would begin the course in the upcoming fall semester. The open letters would inform and advise incoming students about the course; no further guidelines were provided concerning the content of the letters. It was made clear that all the open letters would be made public and that all letters would be posted on the laboratory walls for perusal by the incoming students, staff, and visitors. For taking time to write the letter, participating students were to be awarded two extra credit points on their final exam. On the last day of class in 2015 (2014/2015 cohort), 137 students turned in letters; on the last day in 2016 (2015/2016 cohort), 146 students turned in letters.

The richness of the open letters had not been anticipated. The letters provided an authentic student perspective of the anatomy/physiology course; in particular, they described what students thought they needed to do in order to pass the course. The open letters presented an opportunity to understand the difficulties and challenges of the course from the students’ perspectives, which would inform the teaching practices for future anatomy/physiology course. The next year, the same opportunity was made available for the 2015/2016 student cohort who completed the course, providing an opportunity to see how the comments compared. The two sets of essays provided the qualitative data examined in this study to explore how students perceived the anatomy/physiology course. This project was considered exempt and approved by the Institutional Review Board (IRB) of Ohio University (15E265), as this was a voluntary student project in which participants understood the letters were to be made public.
Analysis
Evaluation of the data was compatible with qualitative analysis methods because the data was composed of the students’ voices (Creswell 2013; Stake 1995; Stake 2010; Yin 2009; Yin 2011). A case study design was used to examine the students’ perspectives of the anatomy/physiology course. This study utilized the open letters for analysis, to search for patterns of common meaning derived from the students’ letters, ultimately resulting in a final description. The study was bounded by all the essays received, regardless of their content (Yin 2009). In vivo, or literal coding, was used because the intent of this study was to examine the student perspectives through the students’ own words (Manning 2017; Saldana 2016). The participants’ words became the codes. In vivo coding is appropriate when the participant’s voice is the priority. All the essays were coded for insightful vocabulary and emergent themes, with the intent to identify each student’s perception of the anatomy/physiology course, and how the anatomy/physiology course affected their lives. The emergent themes were examined and evaluated to help answer the research questions.

Validation and Credibility
All essays were coded for data and none were excluded for any reason. The first step was to create a thick, rich description of this anatomy/physiology course from which the students generated their experiences. The goal of this paper is to provide context to help the readers understand the students’ perspectives. The readers can then transfer those findings to their own personal perspective and then interpret the data for themselves (Creswell 2013; Patton 2002; Polkinghorne 1989). This study utilized reflexivity to bracket or separate the researcher’s biases from the data (Creswell 2013; Moustakas 1994; Patton 2002; Polkinghorne 1989; Yin 2011). Negative case analysis examined data that did not fit with the identified patterns and themes and discussed why the negative data did not fit (Creswell 2013; Polkinghorne 1989). Finally, a science education academic professional who had no connection to the study performed an external audit. The external auditor examined the accuracy of the study’s data, process, analysis, and conclusions (Creswell 2013; Patton 2002).

Limitations
There were three limitations in this study. First, the participants were limited to the students who finished both semesters of the anatomy/physiology course. The study did not include students from the first semester who did not take the second semester portion, or students who withdrew from the course. Second, time was a limitation since this study is examining only two years. Third, the data is limited to only one university. Limitations were dictated by the boundaries of this study, which were originally intended to inform the students and faculty of this course. Despite the limitations, this study offers insight towards student perspectives from the required anatomy/physiology courses for non-biology majors, including nursing, nutrition, public health, and family science majors.

Results
A priori categories were explored as themes or categories that were being developed. Braund and Reis (2006) discussed five primary themes after exploring hands-on, experiential learning activities: Social involvement, Hands-on, Surprise, Novelty, and Knowledge acquisition. These themes can be extrapolated from the results of our study and parallels can be seen; however, the comparisons are strained. In our study, surprise and novelty were not obvious in the students’ comments, although social involvement, hands-on, and knowledge acquisition were easily evident. However, these categorizations do not relate to the unique story of each individual’s perceptions of what is needed to successfully complete an anatomy/physiology course.

In vivo coding, using a student’s own words to remove researcher interpretation bias, attempted to capture each student’s intended perception through his or her comments. Tables 1-6 illustrate the categories and specific codes identified from the essays. The essays from 2014/2015 and 2015/2016 presented similar numbers of codes under each category; therefore both sets of data were combined as one full data set.
Student Perception of How to Succeed in a Pre-Nursing Anatomy and Physiology Course

Table 1 shows the codes relating to lectures. Roughly half of the students recognized that the daily clicker quiz was important for their grade, while only a fifth of the essays suggested attending every lecture. Only 2% suggested putting away their phones.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicker Quiz - study for/important</td>
<td>64</td>
<td>66</td>
<td>130</td>
<td>46%</td>
</tr>
<tr>
<td>Always attend lecture</td>
<td>27</td>
<td>32</td>
<td>59</td>
<td>21%</td>
</tr>
<tr>
<td>Need/use colored pencils, highlighters</td>
<td>17</td>
<td>6</td>
<td>23</td>
<td>8%</td>
</tr>
<tr>
<td>Print notes for lecture</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>3%</td>
</tr>
<tr>
<td>Take notes</td>
<td>8</td>
<td>8</td>
<td>16</td>
<td>3%</td>
</tr>
<tr>
<td>Put phone away</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2%</td>
</tr>
<tr>
<td>Draw charts, pictures, flowcharts for understanding</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>2%</td>
</tr>
<tr>
<td>Record Lecture</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>1%</td>
</tr>
<tr>
<td>Sit in front of class</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Need blank paper to draw on in lecture</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>1%</td>
</tr>
<tr>
<td>Prepare self for next lecture/class</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Practice exams in book</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Know chapter two</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Wish was told pointers and tips</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Do not leave lecture early</td>
<td>1</td>
<td>1</td>
<td>&lt;1%</td>
<td></td>
</tr>
<tr>
<td>Print guided notes in color</td>
<td>1</td>
<td>1</td>
<td>&lt;1%</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Codes Relating to Lecture n = 283

Table 2 shows the codes relating specifically to exams, which were the primary basis for the final grade. The only significant comment was to begin studying a week prior to the announced exam. There was little consensus concerning study skills.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begin studying 7 days or more before next exam</td>
<td>29</td>
<td>31</td>
<td>60</td>
<td>21%</td>
</tr>
<tr>
<td>Exams based on notes</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>Begin studying less than 7 days in advance</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>No all-nighters</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>No going out for fun weekend before exam</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Make practice exams</td>
<td>1</td>
<td>1</td>
<td>&lt;1%</td>
<td></td>
</tr>
<tr>
<td>Review exams for finals</td>
<td>1</td>
<td>1</td>
<td>&lt;1%</td>
<td></td>
</tr>
<tr>
<td>All-nighter necessary before exam</td>
<td>1</td>
<td>1</td>
<td>&lt;1%</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Codes Relating to Exams n = 283
Table 3 shows the codes specific to studying and study skills. Several codes were regularly identified. Nearly half the students recommended study groups or studying with friends. One third of the students recommended studying every day and reading the textbook. Not waiting until the last moment to study or cramming for exams was mentioned by 28% of the students. The remaining codes provide insight into how students prepare for exams.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Group/ friends</td>
<td>58</td>
<td>69</td>
<td>127</td>
<td>45%</td>
</tr>
<tr>
<td>Study every day</td>
<td>65</td>
<td>37</td>
<td>102</td>
<td>36%</td>
</tr>
<tr>
<td>Read book</td>
<td>34</td>
<td>52</td>
<td>86</td>
<td>30%</td>
</tr>
<tr>
<td>Don’t procrastinate/cram</td>
<td>31</td>
<td>47</td>
<td>78</td>
<td>28%</td>
</tr>
<tr>
<td>Didn’t know how to study/ need to learn how to study</td>
<td>7</td>
<td>26</td>
<td>33</td>
<td>12%</td>
</tr>
<tr>
<td>Rewrite notes</td>
<td>17</td>
<td>16</td>
<td>33</td>
<td>12%</td>
</tr>
<tr>
<td>Review notes after class asap</td>
<td>26</td>
<td>26</td>
<td>52</td>
<td>9%</td>
</tr>
<tr>
<td>Must understand the material, not memorize</td>
<td>9</td>
<td>12</td>
<td>21</td>
<td>7%</td>
</tr>
<tr>
<td>Find a successful way to study</td>
<td>14</td>
<td>14</td>
<td>28</td>
<td>5%</td>
</tr>
<tr>
<td>Use Quizlet</td>
<td>5</td>
<td>8</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>College different from high school</td>
<td>5</td>
<td>8</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>Flash cards</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>3%</td>
</tr>
<tr>
<td>Record the lecture</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2%</td>
</tr>
<tr>
<td>Keep a big binder for all papers</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>1%</td>
</tr>
<tr>
<td>Read notes at least one time a week</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Don’t read book - except to answer a question/ waste of study time</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Read previous class notes prior to lecture</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Study at least a couple times a week</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Learn the intro chapters</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Google slides</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

Table 3. Codes Relating to Study Skills n = 283
Table 4 shows codes relating to the laboratory, a weekly two-hour activity-based scheduled class. Less than a quarter of the students commented on preparing in advance for each lab. Anatomy and Physiology Revealed (APR), a virtual dissection program that constituted a part of each weekly prelab activity (McGraw Hill, 2020), was identified, but with various meanings. Students suggested doing the APR assignments, some students went further to indicate that they not only did the assignment, but they created PowerPoint documents using the APR images. A few students perceived APR as optional, annoying, and tedious.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power point with APR to study</td>
<td>25</td>
<td>41</td>
<td>66</td>
<td>23%</td>
</tr>
<tr>
<td>Do APR</td>
<td>32</td>
<td>23</td>
<td>55</td>
<td>19%</td>
</tr>
<tr>
<td>Do prelabs</td>
<td>17</td>
<td>30</td>
<td>47</td>
<td>17%</td>
</tr>
<tr>
<td>Lab Quizzes matter</td>
<td>18</td>
<td>31</td>
<td>49</td>
<td>17%</td>
</tr>
<tr>
<td>Take pictures/ record models, slides etc.</td>
<td>22</td>
<td>22</td>
<td>44</td>
<td>8%</td>
</tr>
<tr>
<td>Open lab</td>
<td>5</td>
<td>11</td>
<td>16</td>
<td>6%</td>
</tr>
<tr>
<td>Stay in lab the entire time</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>Participate in lab/ no phones/ do dissections</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>Use lab to learn lecture concepts</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>Unpleasant smells and/or images</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>APR is tedious and annoying</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>APR is optional</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Don’t skip models</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Gloves are gross</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Don’t take Tuesday lab</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

Table 4. Codes Relating to Laboratory n = 283

Table 5 shows codes relating to available resources for support to help students through the course. Student Instructor (SI) sessions in the evening and office hours with the lead professor were recognized in one third of the essays. Other options mentioned were meeting with the professor but not during office hours and using multiple library support options.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI sessions</td>
<td>33</td>
<td>60</td>
<td>93</td>
<td>33%</td>
</tr>
<tr>
<td>Attend office hours</td>
<td>38</td>
<td>51</td>
<td>89</td>
<td>31%</td>
</tr>
<tr>
<td>Talk to professors</td>
<td>32</td>
<td>26</td>
<td>58</td>
<td>20%</td>
</tr>
<tr>
<td>Review sessions</td>
<td>16</td>
<td>36</td>
<td>52</td>
<td>18%</td>
</tr>
<tr>
<td>Alden Library</td>
<td>18</td>
<td>23</td>
<td>41</td>
<td>14%</td>
</tr>
<tr>
<td>Use resources available</td>
<td>19</td>
<td>21</td>
<td>40</td>
<td>14%</td>
</tr>
<tr>
<td>Tutoring at library</td>
<td>8</td>
<td>12</td>
<td>20</td>
<td>7%</td>
</tr>
<tr>
<td>Get help</td>
<td>16</td>
<td>16</td>
<td>32</td>
<td>11%</td>
</tr>
<tr>
<td>TA</td>
<td>6</td>
<td>3</td>
<td>9</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 5. Codes Relating to Resources n = 283
Table 6 shows the codes in which students made statements explaining what one needs to do to pass the course. One third of the essays recommended making an effort and studying every day. One fifth of the essays recommended attending every class and doing pre-labs. An additional group of essays acknowledged studying without offering any time recommendations. The remainder consists of specific recommended actions students should follow to succeed in the course.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Put in time and effort</td>
<td>36</td>
<td>57</td>
<td>93</td>
<td>33%</td>
</tr>
<tr>
<td>Study every day</td>
<td>57</td>
<td>37</td>
<td>94</td>
<td>33%</td>
</tr>
<tr>
<td>Always attend lecture</td>
<td>27</td>
<td>32</td>
<td>59</td>
<td>21%</td>
</tr>
<tr>
<td>Study - no time given</td>
<td>60</td>
<td>60</td>
<td>120</td>
<td>42%</td>
</tr>
<tr>
<td>Do prelabs</td>
<td>17</td>
<td>30</td>
<td>47</td>
<td>17%</td>
</tr>
<tr>
<td>Didn’t know how to study/ need to learn how to study</td>
<td>7</td>
<td>26</td>
<td>33</td>
<td>12%</td>
</tr>
<tr>
<td>Need to focus/ prioritize, dedicate self</td>
<td>28</td>
<td>28</td>
<td>56</td>
<td>19%</td>
</tr>
<tr>
<td>Keep up with work</td>
<td>15</td>
<td>15</td>
<td>30</td>
<td>10%</td>
</tr>
<tr>
<td>Find a successful way to study</td>
<td>14</td>
<td>14</td>
<td>28</td>
<td>9%</td>
</tr>
<tr>
<td>College different from high school</td>
<td>5</td>
<td>8</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>Take notes</td>
<td>8</td>
<td>8</td>
<td>16</td>
<td>5%</td>
</tr>
<tr>
<td>Put phone away</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2%</td>
</tr>
<tr>
<td>Keep up with other courses</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
<tr>
<td>Stay in lab the entire time</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>2%</td>
</tr>
<tr>
<td>Participate in lab/ no phones/ do dissections</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>2%</td>
</tr>
<tr>
<td>Prepare self for next lecture/class</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table 6. Codes Identifying Essential Student Expectations of How to Pass the Course n = 283
Table 7 identifies the key words in the essays. More than half of the essays identified the course using the word “difficult” or “hard”, followed by challenging. One third commented on the teachers’ caring and concern about students succeeding in the course. There is a mix of negative and positive words. The fourth most common word involved crying, followed by need to relax, and stressful, while the fifth most common set of terms suggesting the course was interesting and amazing.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
<th>% of n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficult/hard</td>
<td>75</td>
<td>90</td>
<td>165</td>
<td>59%</td>
</tr>
<tr>
<td>Challenging</td>
<td>40</td>
<td>62</td>
<td>102</td>
<td>36%</td>
</tr>
<tr>
<td>Teacher cares about student success</td>
<td>21</td>
<td>71</td>
<td>92</td>
<td>33%</td>
</tr>
<tr>
<td>Crying</td>
<td>18</td>
<td>29</td>
<td>47</td>
<td>17%</td>
</tr>
<tr>
<td>Interesting/ fascinating/ amazing</td>
<td>27</td>
<td>12</td>
<td>39</td>
<td>14%</td>
</tr>
<tr>
<td>Need to relax/ do fun stuff</td>
<td>22</td>
<td>12</td>
<td>34</td>
<td>12%</td>
</tr>
<tr>
<td>Cannot play/ no partying/ no free time like friends</td>
<td>20</td>
<td>14</td>
<td>34</td>
<td>12%</td>
</tr>
<tr>
<td>Stressful</td>
<td>18</td>
<td>15</td>
<td>33</td>
<td>12%</td>
</tr>
<tr>
<td>Praises professor</td>
<td>33</td>
<td></td>
<td>33</td>
<td>12%</td>
</tr>
<tr>
<td>Important/ valuable</td>
<td>30</td>
<td>30</td>
<td>60</td>
<td>11%</td>
</tr>
<tr>
<td>Time management</td>
<td>15</td>
<td>13</td>
<td>28</td>
<td>10%</td>
</tr>
<tr>
<td>Be optimistic/ positive/ believe in self</td>
<td>16</td>
<td>12</td>
<td>28</td>
<td>10%</td>
</tr>
<tr>
<td>Requires hard work</td>
<td>29</td>
<td>12</td>
<td>41</td>
<td>10%</td>
</tr>
<tr>
<td>Rewarding</td>
<td>18</td>
<td>9</td>
<td>27</td>
<td>10%</td>
</tr>
<tr>
<td>Overwhelming</td>
<td>13</td>
<td>10</td>
<td>23</td>
<td>8%</td>
</tr>
<tr>
<td>Prepare for future</td>
<td>21</td>
<td>21</td>
<td>42</td>
<td>7%</td>
</tr>
<tr>
<td>Will fail along the way</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>7%</td>
</tr>
<tr>
<td>Fun</td>
<td>15</td>
<td>3</td>
<td>18</td>
<td>6%</td>
</tr>
<tr>
<td>Loss of sleep</td>
<td>1</td>
<td>12</td>
<td>13</td>
<td>5%</td>
</tr>
<tr>
<td>Worth it in the end</td>
<td>6</td>
<td>9</td>
<td>15</td>
<td>5%</td>
</tr>
<tr>
<td>Want to quit at times</td>
<td>8</td>
<td>7</td>
<td>15</td>
<td>5%</td>
</tr>
<tr>
<td>Question one’s major</td>
<td>14</td>
<td>14</td>
<td>28</td>
<td>8%</td>
</tr>
<tr>
<td>Do not be discouraged</td>
<td>12</td>
<td>12</td>
<td>24</td>
<td>4%</td>
</tr>
<tr>
<td>Have fun in class</td>
<td>12</td>
<td>12</td>
<td>24</td>
<td>4%</td>
</tr>
<tr>
<td>Best class ever had</td>
<td>1</td>
<td>8</td>
<td>9</td>
<td>3%</td>
</tr>
<tr>
<td>Major sacrifices</td>
<td>9</td>
<td>9</td>
<td>18</td>
<td>3%</td>
</tr>
<tr>
<td>Failed because did not do the work</td>
<td>8</td>
<td>8</td>
<td>16</td>
<td>2%</td>
</tr>
<tr>
<td>Frustrating</td>
<td>7</td>
<td>7</td>
<td>14</td>
<td>2%</td>
</tr>
<tr>
<td>Discouraging</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>2%</td>
</tr>
<tr>
<td>Grade due to own effort</td>
<td></td>
<td>6</td>
<td>6</td>
<td>2%</td>
</tr>
<tr>
<td>Learn amazing things</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>2%</td>
</tr>
<tr>
<td>Don’t panic</td>
<td>6</td>
<td>6</td>
<td>12</td>
<td>2%</td>
</tr>
<tr>
<td>Late nights</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>1%</td>
</tr>
<tr>
<td>Get used to low grade</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>1%</td>
</tr>
</tbody>
</table>

*Table 7. Most Common Key Terms used in Essays n = 283*
Table 8 identifies the less common key words identified in the essays. Although only one to four essays provided these words or concepts, many of these lesser-used terms provide a glimpse into student perceptions of students who may have struggled in the course.

<table>
<thead>
<tr>
<th>Code</th>
<th>2015</th>
<th>2016</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haunt</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Compared to having a child</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Don’t cheat</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Intimidated</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Learn about self, self-identification</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Beneficial</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Appears impossible and scary</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Good feeling at end of course</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Don’t compare self to others</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Passion/passionate</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Terrified</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Wished would have put in more time</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Need to be organized</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Trust the professor</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Exhausting</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Scary</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hell</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Terrible</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Drop the course if you need to</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Hell - but worth it</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Appreciate material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great experience</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No fun in college life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freaking out</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Prepare for failure</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Depths of hell</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Need to be focused</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Ridiculous course speed</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Don’t drink/ get caught/ dropped from nursing program</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Share what learned with parents</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Seems impossible at times</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Want to give up</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Makes you feel stupid</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Course not impossible</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Be prepared every day</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Can succeed</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>No social life</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

*Table 8. Less Common Key Terms used in Documents n = 283*
Student Perception of How to Succeed in a Pre-Nursing Anatomy and Physiology Course

Table 9 is intended to show the most positive and the most negative student perceptions. The columns are unique and stand-alone but show an intense separation of positive and negative insights.

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher cares about student success</td>
<td>Crying/ Freaking out/ screaming</td>
</tr>
<tr>
<td>Need to relax/ do fun stuff</td>
<td>Cannot play/ no partying/ no free time like friends/ no fun</td>
</tr>
<tr>
<td>Praises professor</td>
<td>Stressful/ overwhelming/ frustrating</td>
</tr>
<tr>
<td>Important/ valuable</td>
<td>Hell/ Depths of Hell</td>
</tr>
<tr>
<td>Be optimistic/ positive/ believe in self</td>
<td>Will fail along the way/ want to quit</td>
</tr>
<tr>
<td>Rewarding</td>
<td>Question one’s major</td>
</tr>
<tr>
<td>Fun</td>
<td>Loss of sleep</td>
</tr>
<tr>
<td>Worth it in the end</td>
<td>Terrible/ discouraging</td>
</tr>
<tr>
<td>Great experience</td>
<td>Makes you feel stupid</td>
</tr>
<tr>
<td>Have fun in class</td>
<td>Get used to low grade</td>
</tr>
<tr>
<td>Best class ever had</td>
<td>Exhausting</td>
</tr>
<tr>
<td>Good feeling at end of course</td>
<td>Compared to having a child</td>
</tr>
<tr>
<td>Interesting/ fascinating/ amazing</td>
<td>Appears impossible and scary</td>
</tr>
<tr>
<td>Beneficial</td>
<td>Prepare for failure</td>
</tr>
<tr>
<td>Learn amazing things</td>
<td>Seems impossible at times</td>
</tr>
<tr>
<td></td>
<td>Don’t drink and get caught or dropped from nursing program</td>
</tr>
</tbody>
</table>

Table 9. Compare and Contrast of Key Terms from Students in the Same Course

Table 10 identifies five words or concepts of concern, indicating how often that term was used. We do not know if these students passed or failed, but the terms clearly suggest that these students struggled.

<table>
<thead>
<tr>
<th>Vocabulary</th>
<th># Times Word Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stressful/ overwhelming/ frustrating</td>
<td>63</td>
</tr>
<tr>
<td>Crying/ Freaking out/ screaming</td>
<td>50</td>
</tr>
<tr>
<td>Cannot play/ no partying/ no free time like friends/ no fun</td>
<td>35</td>
</tr>
<tr>
<td>Will fail along the way/ want to quit</td>
<td>35</td>
</tr>
<tr>
<td>Hell/ Depths of Hell</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 10. Words and Terms of Concern
Each essay constituted a data set. At the end of the two-term course, students were told to write a letter to students beginning the anatomy course in the fall, to communicate what they had learned about how to pass the course. Because no other guidelines were provided, there was a wide range of topics and commentary. Data consisted of themes and vocabulary identified through qualitative coding. Although each essay is an individual student’s voice, the focus of this study was to identify themes. Individual students were not recognized in this analysis, although representative statements have been provided as examples.

Peer Teaching
A topic common to 45% of the essays involved some sort of peer teaching, which included study buddies, student formed study groups, and scheduled teacher assistant and student instructor (TA/SI) sessions:

(Student Essay 14)
I wouldn’t have survived without my friends in (the course.) This doesn’t mean you have to study with them all the time, because you may be like me and study better on your own, but it’s always helpful when they can quiz you on the material.

(Student Essay 150)
My first exam I thought I could study by myself and would be fine, but then reality hit when I got a D on the first exam. I found a friend in my learning community who has been my study buddy all the way until the end of the course. It helps to read your notes to each other and ask questions about it. Challenge each other!

The participants through their essays explained that study buddies from class provided an understanding partner who was experiencing the same lectures and labs. Other essays recognized the value of peer teaching:

(Student Essay 171)
Develop friends and study buddies and study groups. You will need to study on your own, but going over notes and talking about important topics with another person will help you, and the people you study with, understand the material much more easily.

The formal peer teaching SI sessions were recommended by 33% of the participants in their essays:

(Student Essay 191)
SI sessions give you the opportunity to meet with people in your class and go over the notes in question form. Any questions you may have can be answered by the SI leader. They truly do their best to help.

Professor as a resource
Another common topic involved the professor’s availability outside of the classroom: 33% of the essays explained that the professors cared about students succeeding, 31% of the essays recommended attending open office hours, and 20% recommended talking to the professors:

(Student Essay 50)
(Professor) is an extremely fair teacher, don’t talk s--- about her because you’ll just look stupid. She knows her stuff and wants you to know your stuff as well. Her expectations are high, you don’t want to let her down because it is very rare to have a professor in college that believes in you like she does. A professor that cares, and strives to do her absolute best so her students see the benefits.

(Student Essay 13)
Go to office hours to get your questions answered. Many people believe that this is “brown nosing” but this is college now and some of the best relationships you can make will be with your professors.

(Student Essay 211)
This is one thing that I did not do but wish I had. Learn from my mistake and visit (Professor) often. She is very intelligent, easy to talk to, and really wants her students to do well.

Time management and life balance
Time management was a common theme throughout the essays, although there was no specific topic. Most common was the general idea to study every day (36%). Other time management comments focused on participation in social activities:

(Student Essay 12)
…cannot play/no partying/no time for friends/ need to relax and do fun stuff.

(Student Essay 30)
You are not going to be able to go out as much as your friends…There will be kids in our class that go out almost all the time and you will see them fail the class.
Affective effects – emotions – trauma- life changing
Many of the essays contained strong negative affective vocabulary:

(Student Essay 33)
You probably heard how horrible, difficult and time consuming this class is. As bad as that sounds, it will feel 10x worse. Most of you will have a couple mental breakdowns, want to give up.

(Student Essay 18)
There are going to be times where you feel like giving up, but you must remind yourself that all your hard work and struggle will pay off in the end. It is okay to have a breakdown or shed a few tears.

(Student Essay 205)
Work hard, shed tears, pull all-nighters, be great!

(Student Essay 285)
There may be times you want to bang your head against the wall multiple times, or rip all your notes apart, but do not give up. There may be times you have to sacrifice going out with your friends or watching Netflix that night, but it has to be done!

Student preparedness for course
A considerable volume of research has been conducted concerning student preparedness for college. However, through the essays, students revealed their perceptions of their own preparedness for this college course:

(Student Essay 72)
I wish someone would have given me a heads up or tips on this class before I started. The best tip I have is to study, study, study.

(Student Essay 33)
For the first semester I had no idea how to study, so I was constantly digging myself out of a hole.

(Student Essay 205)
College is such a new, shiny, confusing place. You get so many people telling you what you should and shouldn’t do but you really won’t know what college is until you’ve done it.

(Student Essay 11)
The first time I took it, I didn’t take the class seriously. I didn’t put in the time to understand the material before each lab and lecture. I thought that I could get by through cramming the day before an exam. I learned the hard way that getting by is not the way to succeed in this class. Nobody wants to be treated by a medical professional like a nurse who just “got by” in their classes. The second time I took (the course), I entirely changed my tactics. I worked on my study skills, dedicated hours and hours every week towards rewriting lecture notes, had group study sessions, made countless PowerPoints for lab, and made sure to not neglect the clicker and lab quizzes.

(Student Essay 213)
NEVER start studying for an exam the night before. This is nothing like high school, if you do that you will not do well. You have to be willing to put the time in to studying so that you actually understand it, not just memorized it.

Student perceptions for success techniques
Related to perception of preparedness, the essays also revealed students’ perceptions of what should be done to succeed in passing anatomy/physiology:

(Student Essay 12)
I tended to cram the night before and would get a 83% so if you can cram I would 10/10 recommend it!

(Student Essay 20)
You are not just trying to pass a class – you are learning so that you can save lives.

(Student Essay 16)
Do not use your phone in class! You seriously will miss something important. I learned that the hard way!

(Student Essay 48)
I was pretty proud that I didn’t miss a class all semester, but I realized that’s what the successful students do.

(Student Essay 41)
Get down and dirty in lab – participate! Hold the organs, look at the cadaver, be hands on!

(Student Essay 72)
I wish I would have utilized (professor’s) office hours and recitation.

(Student Essay 147)
You are not given a grade…you earn a grade here.

Student Essay 285
If you want to succeed you need to actually learn and understand the material. DO NOT just memorize, trust me. I did that at first! Everything ties together and if you do not actually know the material, you are screwed.

(Student Essay 12)
Don’t drink alcohol in a public space bk you will get caught by undercovers and will be unable to join the nursing program.
Discussion

The essays provided a means to observe students’ thinking and perspectives of the anatomy/physiology course, and provided evidence of each student’s perspective of priorities, skills, and understandings that they possessed or lacked. The general categories, identified from the codes from essays that illustrated each student’s voice, were examined to help answer the research questions.

What skills did the students perceive as important or necessary in order to pass the course? Evidence to respond to the primary question was empirically derived directly from the essays. Students recognized the need to study, which needed to be focused and performed daily. There was a strong acknowledgement to attend each lecture and to prepare prior to each lecture for a daily opening quiz. Study skills were identified in small segments. Test preparation should begin seven or more days before the next exam. A small group recommended rewriting notes, while a smaller subset recommended keeping up with the work. Supported by Fletcher and Tienda (2009a), who describe the value of peers and college success, many students recognized the importance of working with peers through study groups and peer teaching.

What gaps in pre-college preparation for the course were identified? This can be answered by looking at student perceptions about what is needed for success. The skills described are basic study skills, and although some students seemed to understand these expectations, many students commented as if this was a new concept for them. “Do not use your phone in class! You seriously will miss something important. I learned that the hard way!” (Student Essay 16). “I was pretty proud that I didn’t miss a class all semester, but I realized that’s what the successful students do” (Student Essay 48). Twelve percent of the essays indicated that the writer did not know how to study and needed to learn how to study.

These students were not new to academia. They needed to graduate from high school with better than a 3.0 grade point average and needed to have taken a pre-college course load. Most of these students were striving to earn a nursing or nutrition BS degree, which required a C or better grade in anatomy/physiology. The combined 2014/2015 and 2015/2016 first semester anatomy/physiology course drop out and failure rate was 29%. If the failures include the letter grade D, which earned the student credit for the course but is still considered failing, the drop out and failure rate was 46%. This supports the suggestion that many students entering college lack learning skills and do not understand how to develop learning skills (Ding and Mollohan 2015; Hammer and Elby 2003; Moore and Rubio 2012).

Further insight was provided by the third question, how did the students perceive the course? The majority of essays began with a statement inferring that the course was difficult and challenging. Table 9 compared and contrasted vocabulary. The positive words were more cognitive, the negative words were more affective: Teacher cares about student success, Need to relax/ do fun stuff, etc., compared to Crying/ Freaking out/ screaming, Cannot play/ no partying, etc. The negative vocabulary suggests that students may have been struggling, although some may have done well but disliked the course. Those who struggled may have lacked the scaffolding required to feel comfortable with the course’s depth, breadth, and speed. This supports the possibility that their high school courses lacked rigor; a concept supported by previous research. Lewin (2005) indicated that less than half of college bound students were prepared to take college level science classes. Incoming college students lacked the knowledge of how to develop learning skills (Ding and Mollohan 2015; Hammer and Elby 2003; Moore and Rubio 2012), and roughly two-thirds of all high school graduates are unprepared for college and struggle to succeed in college (Balfanz 2009; Greene and Forster 2003).

Interest and curiosity, time management skills, and general life skills are also recognized as important factors determining student success (Conley 2014). However, in this study, interest and curiosity were minimally observed among the vocabulary words and codes. The only codes that suggested interest and curiosity were interesting/fascinating/amazing (14%), fun (6%), learn amazing things (2%), appreciate the material (1%), and great experience (1%). Many students did not understand the commitment and time management required to enter a program leading to a professional career. Twelve percent of students decried that they had little time to go partying with friends and 10% recognized they needed to develop time management skills. Essentially, the essays suggested that many students needed to develop necessary learning skills as the course proceeded.

These insights can help the anatomy/physiology faculty better prepare for the incoming students’ personal beliefs and understandings of what those students think is necessary to successfully pass the course. The results of this study promote the question: Should faculty dedicate time at the beginning of the course to encourage and nurture a paradigm shift among student thinking in order for the students to succeed in the course?
Conclusion
Much of the data acquired from the essays suggests that there is a gap between the present high school course framework and competencies required to take college level anatomy/physiology, and for many, to enter the nursing program. Our findings align with studies that demonstrated how students entering engineering programs could not meet the competencies required by practicing engineers (Jang 2015). STEM courses are required to enter college science major programs, yet, this study and other research suggest that the high school STEM courses need to be redesigned to teach learning skills and develop higher rigor competencies if students are to succeed in a college level anatomy/physiology course and nursing program. These results indicate a need for improvement in both high school and community college student preparation and support.

With a nursing shortage already documented (Rosseter 2019), the importance of university nursing programs has been highlighted by the COVID-19 pandemic of 2020 (Connolly et al. 2020; Pearce 2020). In order to enter a nursing program, students are required to have STEM core knowledge and learning skills. When half of those qualified students fail their first anatomy/physiology course, the program has wasted considerable resources, and perhaps turned away viable program candidates at the screening level. The data in this study provides nursing programs and instructors a new lens through which to consider how an anatomy/physiology course may be able to generate and increase student learning success.

Issues Identified
- Many incoming college students entering anatomy/physiology courses were unprepared for college.
- There is a need for student support to compensate for inadequacies and affective needs.
- Successful students have appropriate learning skills and develop pride in their accomplishments.

Future Research
Future research will be necessary to understand the full depth and breadth of entering college freshmen preparedness in general and when taking anatomy/physiology courses. What is the pattern of student realization that the present study methods are not working? How do study skills develop from the beginning of the first semester to the end of the second semester? A longitudinal study might examine the high school background of students who succeeded from the beginning. Would a pre-college skills camp enable student success in college science courses?

From a broader perspective, how prepared are urban versus rural high school students when they advance to college level science courses? Are students who take advance placement courses better prepared to take college-level science courses? Is there any difference in high school student preparedness for science courses between public, private, and charter high schools? Finally, looking at secondary education objectives, do school systems concern themselves with student efficacy at the university level?

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Low-Stakes vs. No-Stakes Practice Exams in Anatomy and Physiology Classes: Which One Works Better?

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Abstract
Practice exams are a proven tool to increase retrieval of information long-term. Over a three-year period, students in Anatomy and Physiology I and II were offered practice exams as either no-stakes practice exams (years 1-2) and low-stakes practice exams (year 3). Students who took practice exams did significantly better on the actual lecture exams, leading to better grades and higher passing rates for our courses. There was no difference for gender and student population. Students earning credit (low-stakes) were more likely to take the practice exams but their scores on actual exams and their overall scores were lower than those of students who did not earn credit (no-stakes). https://doi.org/10.21692/haps.2020.010

Key Words: no-stakes testing, low-stakes testing, practice exams, Anatomy and Physiology

Introduction
Practice testing can be defined as a low- or no-stakes learning activity completed by students outside of class and/or any type of practice test students are able to complete on their own (Karpicke and Roediger 2007). Practice testing can enhance learning and long-term retention (Agarwal et al. 2012; Roediger and Butler 2011; Dunlosky et al. 2013), and the use of practice testing has been shown to promote learning and retention of content in a more efficient manner than other commonly used study techniques such as repeated reading and repetition (Roediger and Butler 2011). Testing slows forgetting and, consequently, improves the later retrieval of information (Arnold and Mcdermott 2013, Roediger et al. 2011; Utz and Bernacki 2018). Additionally, the attempts to retrieve content through a test may assist students in encoding even if the retrieval attempts were unsuccessful (Dunlosky et al. 2013).

Practice testing can vary in type to include textbook end of chapter reviews, the creation of the learner’s own test questions, writing practice exams under exam-like conditions, flash cards, or teacher created practice tests. The widespread use of learning management systems (LMS) and the availability of free websites that allow users to create tests have made it easier for instructors to offer their students practice tests that are specific to the content taught in their classes. Irrespective of the type of practice test, these tests can be used to effectively enhance learning and long-term retention in students while also measuring the contents of memory (Karpicke and Roediger 2007). If students use the practice exams without earning points or extra credit toward their final course grade, the testing is called no-stakes. In low-stakes testing, students can earn points or extra credit to improve their grade on the actual exam or their final grade in the course.

Davis (2013) opined that using practice exams with multiple choice and true-false questions may be especially suitable for classes that focus on the lower levels of Bloom’s taxonomy (recall, comprehension, and application) that require students to learn a great deal of new terminology and/or facts and figures.

We introduced no-stakes practice testing for both Anatomy and Physiology with Lab I and II courses in Spring semester 2013. Looking at the exam scores and final grades of our students at the end of the semester, it was apparent that students who had taken all four practice exams in preparation for the actual exams had scored higher on the exams. Consequently, they had higher overall scores and more of them earned a passing grade of A, B, or C (80.9% vs. 50.0% for students who did not take any of the practice exams).

Over the next few years, our lab instructors and I educated students about the benefits of taking the online practice exams using updated data from our courses. I presented posters and workshops on the topic on my own or together with co-authors, for example at the 2015 HAPS Conference in San Antonio, TX and the 2015 SoTL Commons Conference in Savannah, GA.

Unfortunately, despite all our efforts, only about two-thirds to three-quarters of students took all of the practice exams offered. Of particular concern was the fact that lower performing students took the practice exams at fairly low rates; sometimes less than one-third of students who scored lower than 70% on an exam had taken the practice exam.
Finally, our lab instructors and I agreed to try using low-stakes practice exams in an effort to entice more students to take the practice exams, hoping that this would lead to better scores on exams, better grades, and higher passing rates. This article will review what happened when we switched to low-stakes practice exams and explore whether or not low-stakes or no-stakes practice exams led to better outcomes in terms of student grades.

**Methods**

**Ethical research statement**

The ethical review board (Institutional Review Board) of Florida Gulf Coast University (FGCU) research protocol approved this project prior to data collection (FGCU IRB Protocol 2014-63). Data collection followed all laws relevant to the survey of university student populations.

**Data collection**

For a two-year period, practice exams were offered as no-stakes, online practice exams for Anatomy and Physiology I (A&P I) and II (A&P II). These practice exams had the same number and type of questions as the actual exams, and the students were able to see more than one question at a time. Students were able to go back and change answers based on information gained from other questions before submitting the exam. The questions were testing the same areas as the questions on the actual exam and the exams had the same balance for the different course modules covered. The students were given the same time to complete the practice exams as on the actual test. They were allowed to retake the practice exams up to three times. After submitting the exam, students were able to see which questions they had answered correctly and which ones they had gotten wrong. However, they were not given the correct answers for questions they got wrong until after the third attempt at taking the practice exam. The practice exams opened ten days before the date of the lecture exam and closed the night before the lecture exam.

For the third year of the study, the practice exams were converted to low-stakes exams, using the same questions as before. The students earned 0.2 point for each correct answer compared to two points for each correct answer on the in-class exam. Students were allowed to take the practice exam up to three times; the LMS kept the highest score.

The practice exams and the actual exams were kept the same throughout the study. The content of the actual exams was well guarded to prevent cheating, but the practice exams could not be controlled in the same way since they were posted to the internet.

Data collection for this article was discontinued after year three due to significant changes in content delivery (some of the courses were offered as hybrid courses with virtual lectures) and course materials used (we switched to a new textbook and lab workbook).

**Data analysis**

A two-sample t-test was used in determining statistical significance for the average exam scores for students who took practice exams versus those who did not.

**Results**

The study population hardly changed over the three-year period data were collected. During years one and two, overall 1,328 students were enrolled in Anatomy and Physiology I courses, although only 982 (73.9%) students took all four exams. Three-quarters of students who took all exams were female (75.4%), one-quarter was male (24.6%). Sophomores made up the bulk of students (57.8%), followed by juniors (19.3%), freshmen (16.3%), and seniors (5.3%). Twelve students (1.2%) were non-degree or second-degree seeking students.

In Anatomy and Physiology II, 586 of 643 enrolled students (91.1%) took all four exams. The female-to-male ratio was similar to Anatomy and Physiology I (73.9% female and 26.1% male). Sophomore students made up slightly more than half the student population (53.2%) and juniors were again the second biggest group at 27.7%. Seniors (9.0%) and freshmen (8.4%) were almost evenly represented; non-degree or second degree seeking students accounted for 1.7%.

In year three, 537 of 706 students enrolled in Anatomy and Physiology I (76.1%) and 338 of 361 students enrolled in Anatomy and Physiology II (93.6%) took all four exams. Most of these students were female (74.5% in Anatomy and Physiology I; 78.1% in Anatomy and Physiology II). Sophomore students still were the biggest group of students in both Anatomy and Physiology I (62.9%) and Anatomy and Physiology II (52.1%), followed by juniors (20.5% in Anatomy and Physiology I; 25.3% in Anatomy and Physiology II). Freshmen made up 11.4% of students who took all four exams in Anatomy and Physiology I and 3.1% in Anatomy and Physiology II. The percentages for seniors were 4.1% for Anatomy and Physiology I and 14.5% for Anatomy and Physiology II; for non-degree or second degree seeking students the percentages were 1.1% for Anatomy and Physiology I and 5.0% for Anatomy and Physiology II.

The percentage of Anatomy and Physiology I students taking no-stakes practice exams was almost constant for exam 1-3 at 71-75% but dropped below 65% for the final exam (Table 1). The corresponding percentages for Anatomy and Physiology II were lower throughout but did not drop as much for the final.
As to be expected, almost 100% of Anatomy and Physiology I and II students took the low-stakes practice exams during year three and the percentage did not drop for the final (Table 1).

Students in both Anatomy and Physiology I and II who took all practice exams as no-stakes exams scored higher on the final exam and had a higher overall exam score than students with low-stakes practice exams. However, the difference in the overall exam score was not significant (Table 2).

<table>
<thead>
<tr>
<th></th>
<th>Exam 1</th>
<th>Exam 2</th>
<th>Exam 3</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No-stakes PE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A&amp;P I (n = 982)</td>
<td>75.1%</td>
<td>71.3%</td>
<td>72.3%</td>
<td>64.9%</td>
</tr>
<tr>
<td>A&amp;P II (n = 586)</td>
<td>68.1%</td>
<td>64.0%</td>
<td>66.4%</td>
<td>62.6%</td>
</tr>
<tr>
<td><strong>Low-stakes PE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A&amp;P I (n = 537)</td>
<td>97.0%</td>
<td>98.1%</td>
<td>98.0%</td>
<td>96.1%</td>
</tr>
<tr>
<td>A&amp;P II (n = 338)</td>
<td>97.1%</td>
<td>97.1%</td>
<td>97.9%</td>
<td>97.9%</td>
</tr>
</tbody>
</table>

Table 1. Percentage of students taking the practice exam for all exams in Anatomy and Physiology I and II as no-stakes or low-stakes practice exams (PE)

<table>
<thead>
<tr>
<th></th>
<th>Score final exam</th>
<th>Overall exam score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No-stakes PE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A&amp;P I (n = 457)</td>
<td>78.7%</td>
<td>78.3%</td>
</tr>
<tr>
<td>A&amp;P II (n = 242)</td>
<td>79.0%</td>
<td>77.1%</td>
</tr>
<tr>
<td><strong>Low-stakes PE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A&amp;P I (n = 490)</td>
<td>75.3%</td>
<td>76.7%</td>
</tr>
<tr>
<td>A&amp;P II (n = 312)</td>
<td>75.0%</td>
<td>75.1%</td>
</tr>
</tbody>
</table>

Table 2. Test scores on final exam and overall exam score for students who took all four practice exams during the semester for Anatomy and Physiology I and II and no-stakes or low-stakes practice exams (PE)
Anatomy and Physiology I and Anatomy and Physiology II students taking no-stakes and low-stakes practice exams practice exams scored significantly higher on each exam (Table 3).

Both female and male students who took no-stakes or low-stakes practice exams scored significantly higher on the actual exams than students who did not take any practice exam during the semester (Table 4). There was no difference for the different student populations (freshman, sophomore, etc.) and whether low-stakes or no-stakes practice exams were offered.

<table>
<thead>
<tr>
<th></th>
<th>Exam I</th>
<th>Exam II</th>
<th>Exam III</th>
<th>Final Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No-stakes PE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>A&amp;P I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took PE</td>
<td>77.9%</td>
<td>77.1%</td>
<td>74.3%</td>
<td>77.2%</td>
</tr>
<tr>
<td>Did not take PE</td>
<td>73.7%</td>
<td>71.3%</td>
<td>63.5%</td>
<td>65.9%</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt; 0.001*</td>
<td>&lt; 0.001*</td>
<td>&lt; 0.001*</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td><strong>A&amp;P II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took PE</td>
<td>73.3%</td>
<td>78.6%</td>
<td>72.3%</td>
<td>78.0%</td>
</tr>
<tr>
<td>Did not take PE</td>
<td>69.3%</td>
<td>73.4%</td>
<td>69.2%</td>
<td>70.0%</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt; 0.001*</td>
<td>&lt; 0.001*</td>
<td>0.036*</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td><strong>Low-stakes PE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>A&amp;P I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took PE</td>
<td>79.7%</td>
<td>75.7%</td>
<td>75.1%</td>
<td>72.0%</td>
</tr>
<tr>
<td>Did not take PE</td>
<td>72.1%</td>
<td>67.3%</td>
<td>64.1%</td>
<td>58.2%</td>
</tr>
<tr>
<td>p-value</td>
<td>0.003*</td>
<td>0.002*</td>
<td>0.011*</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td><strong>A&amp;P II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took PE</td>
<td>76.2%</td>
<td>79.0%</td>
<td>72.8%</td>
<td>74.8%</td>
</tr>
<tr>
<td>Did not take PE</td>
<td>72.1%</td>
<td>71.9%</td>
<td>65.2%</td>
<td>68.3%</td>
</tr>
<tr>
<td>p-value</td>
<td>0.034*</td>
<td>0.032*</td>
<td>0.031*</td>
<td>0.009*</td>
</tr>
</tbody>
</table>

* denotes statistical significance

Table 3. Exam score averages for all four exams for students who took the practice exam (PE) and those who did not. (A two-sample t-test was used in determining statistical significance.)

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A&amp;P I</td>
<td>A&amp;P II</td>
</tr>
<tr>
<td><strong>No-stakes PE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took PE</td>
<td>77.0%</td>
<td>77.5%</td>
</tr>
<tr>
<td>Did not take PE</td>
<td>70.2%</td>
<td>71.3%</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt; 0.001*</td>
<td>0.008*</td>
</tr>
<tr>
<td><strong>Low-stakes PE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took PE</td>
<td>76.9%</td>
<td>78.9%</td>
</tr>
<tr>
<td>Did not take PE</td>
<td>51.0%</td>
<td>72.5%</td>
</tr>
<tr>
<td>p-value</td>
<td>0.003*</td>
<td>0.009*</td>
</tr>
</tbody>
</table>

* denotes statistical significance

Table 4: Comparison of overall test score in exams based on gender based on whether students took the practice exams (PE) versus none.
Discussion
Based on the results of this study, practice exams have to be considered a valuable tool for student success in Anatomy and Physiology I and II classes. Students who took no-stakes or low-stakes practice exams did significantly better on the actual lecture exams, leading to better grades and higher passing rates for our courses. There was no difference in success based on gender and student population.

For the courses with no-stakes practice exams, the percentage of students taking the practice exams was highest before exam 1 for both Anatomy and Physiology I and II, declined slightly for exam 2 and 3, before dropping to its lowest percentage for the final exam. Although there may have been some testing fatigue at the end of each semester, the main reason for the drop for the final exam was that students either knew that they would not be able to earn a better grade or were not in danger of dropping down to a lower grade regardless of their performance on the exam. For example, a student with a pre-final exam overall score of 85% would only need to score 73% on the final exam to earn a B as a final grade; on the other hand, the same student would need to score above 90% to earn a B+. Even though I did not gather survey data on this question, there is anecdotal evidence to back up this hypothesis and the data support it as well. Eighty percent of students who earned an A as a final grade took practice exams one to three but only 73.6% took the practice exam before the final.

As expected, the percentage of students taking low-stakes practice exams remained more or less constant throughout the semester at close to 100%. Even students who had no chance of earning a passing grade took the practice exam before the final exam. The automatic pursuit of “easy” points appears deeply ingrained in many of these students.

At first glance, it is surprising that Anatomy and Physiology I and II students in classes with no-stakes practice exams had higher scores on the final exam and higher overall exam scores on the four lecture exams. After all, fewer Anatomy and Physiology I and Anatomy and Physiology II students took practice exams compared with the classes that took low-stakes practice exams. It was expected that having more students take the practice exams would lead to higher exam scores; this was the reason we made the switch to low-stakes practice exams. The answer to this riddle may lie in the students’ motivation for taking practice exams.

For example, in the no-stakes practice exam classes, of 391 Anatomy and Physiology I students who withdrew from class during the semester, only 89 students (22.8%) took practice exam 1, 42 students took practice exam 1 and 2 (10.7%), and only five students took practice exams 1-3 (1.3%). In contrast to that, of the 110 students who earned a final grade of A, 88 students (80.0%) took practice exams 1-3 and 81 students (73.6%) took all four practice exams. The percentages for Anatomy and Physiology II were similar. A breakdown of when students took the practice exam for the first time reveals that less than a quarter (24.2% in Anatomy and Physiology I; 23.6% in A&P II) took the practice exam for the first time on the day before the actual exam and that 60.8% of Anatomy and Physiology I students and 57.9% of Anatomy and Physiology II students took each practice exam more than once.

Student behavior changed with the switch to low-stakes practice exams. Almost 40% of Anatomy and Physiology I students (39.2%) and more than one-third of Anatomy and Physiology II students (34.6%) took each practice exam for the first time on the last day it was available. More students took the practice exam one time only and up to two-thirds of these students completed the practice exams in less than half the allotted time. Most students scored fairly high on the practice exams; for example, the average score on practice exam 1 was 91.1% while the average score on exam 1 was 79.3%. This difference may be indicative of students using additional input to earn more points on the practice exams. Some students answered all practice-exam questions correctly within a few minutes, consistent with consultation of answer keys on test archive websites such as Quizlet.com or CourseHero.com.

Faculty often received emails from students who asked for permission to take the practice exam after it had been closed because they “needed the points”. Anecdotal evidence from talking to students in class or during office hours also points to students regarding the practice exams mainly as a means to improve their overall grade by earning the points. Our message that retrieval practice improves performance in exams and that taking the practice exams repeatedly enhances long-term retention seemed to be overshadowed by the point value of these practice tests.

Students in Anatomy and Physiology classes usually need the best grades they can get to be admitted to restricted-access undergraduate programs, such as nursing, or graduate school (Occupational Therapy, Physical Therapy, and Physician Assistant) at our institution. Earning an A instead of a B can make all the difference for them. For example, our Exercise Science program requires students to earn a B in both Anatomy and Physiology I and II before they are accepted into upper level classes. Requirements like this cause some students to worry primarily about the grade and not the learning, despite faculty exhortations to the contrary.

After seeing that exam scores and final grades did not change when using low-stakes practice exams, we decided to go back to no-stakes practice exams. We felt that using low-stakes practice exams had caused more pre-exam stress for our students and for us, without improving outcomes. The percentage of students taking practice exams dropped to two-
thirds to three-quarters as the semester progressed. However, when we were forced to switch our in-person classes to online instruction during the Spring 2020 coronavirus pandemic, close to 90% of students in Anatomy and Physiology I and II took the practice exams and almost two-thirds took them more than once. It will be interesting to see whether this experience will change student attitudes toward practice exams when we return to in-person classes.

**Conclusion**

Previous studies have shown that, when used as intended, i.e., as a retrieval practice, practice exams improve student performance in actual exams in science classes. The problem for instructors lies in convincing students that practice exams have value apart from any points that are awarded simply for taking them. Future studies should use surveys or interviews to explore student attitudes toward and opinions on the benefits of practice exams.

**About the Author**

Peter Reuter, MD, PhD, is an Associate Professor at Florida Gulf Coast University where he teaches undergraduate and graduate Anatomy and Physiology courses. He is a member of the Honors College Executive Board and an Honors College Faculty Fellow.

**Literature Cited**


Mentors’ Experience in Teaching Basic Science Concepts in the Community Outreach Program, Anatomy Academy: A Phenomenological Study

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Abstract
This paper analyzes the lived experience of Doctor of Physical Therapy (DPT) students participating in the service-learning program, Anatomy Academy. To understand this experience, we performed a phenomenological analysis using the reflections of 31 DPT students as they participated as Mentors to 5th grade elementary students. Mentors used active learning strategies to teach topics of anatomy, physiology, and nutrition in small groups. After each teaching experience, Mentors responded to writing prompts as a way to reflect upon these experiences. From these reflections, three overarching themes emerged in describing the Mentors' experience. Our results showed that the Mentors developed an understanding of the power in learning through real-world situations, grew in their ability to work with others, and developed an enhanced personal awareness of self and society. This study emphasizes the importance of service learning in the graduate education of DPT students as they progress to become competent health care professionals. https://doi.org/10.21692/haps.2020.017

Key words: basic sciences education, graduate students, mentors’ perspective, phenomenology, preclinical service learning

Introduction
Service learning can be described as an opportunity to apply knowledge and principles from formal education to benefit the members of a community and in turn, enhance the learning of the participant through hands-on experience and real-life situations (Valerius and Hamilton 2001; Munter 2002; Diaz et al. 2019). Service learning also provides an environment for the participant to develop interprofessional teamwork skills, self-awareness, social responsibility, professional skills, and career-related activities (Astin and Sax 1998; Eyler and Giles 1999; McKenna and Rizzo 1999; Primavera 1999; Gray et al. 2000; Valerius and Hamilton 2001; Moely et al. 2002; Bennett et al. 2003; Diaz et al. 2019). Service learning is unique from other types of learning or from volunteering, as participants and recipients in the program benefit symbiotically (Sigmon and Pelletier 1996).

Anatomy Academy is described as a service-learning experience for both undergraduate and graduate students participating as Mentors to elementary school children (Students) in interactive teaching and learning experiences (Diaz et al. 2019). Mentoring is an educational approach in developing a student’s ability to work with others, resolve conflict, understand the value of community involvement, and build leadership skills (Barton-Arwood et al. 2000; Wells and Grabert 2004). Mentoring is an experience that allows the participant to apply knowledge in a real-world setting, examine self and society, and grow in confidence (Schmidt et al. 2004). Mentoring benefits the participant in many different ways, including improvement in content delivery and professionalism (Diaz et al. 2019).

The small, private university in the Midwest where this research was conducted recently added a Doctor of Physical Therapy (DPT) program. One of the program’s missions is to collaborate as community partners to work with underserved populations in Northwestern Iowa. The program’s mission and values align with the American Physical Therapy Association (APTA) as the program seeks to develop DPT students as health care professionals that will contribute to their future community. The APTA has adopted a set of core values of professionalism related to physical therapy practice, education, and research (APTA 2003). These core values include accountability, altruism, compassion/caring, excellence, integrity, professional duty, and social responsibility (APTA 2003).
The Anatomy Academy program was used with the idea that mentoring will begin to shape the graduate students’ professionalism (Steed 2015) that would be beneficial to the DPT students’ progression in becoming a competent physical therapist and to serve the elementary students at a multicultural, low income school. In addition, this experience gave the DPT students an uncommon opportunity to teach, as there are a lack of preclinical teaching opportunities for health care professionals (Diaz et al. 2019). Teaching is a vital skill for health care professionals that may be overlooked in preclinical education. However, it is a necessary component to their postgraduate profession as they continually perform this task with patients daily, and as such, preclinical teaching opportunities should be a focus for health care professionals. There are a number of documented benefits of being a mentor; however, this may be the first research addressing the lived experience of DPT students as Mentors in a service-learning program.

The purpose of this research was to describe the meaning of the Mentors’ experience while participating in the outreach program, Anatomy Academy. Our goals for the research are to determine if DPT students developed core values of professionalism in physical therapy as determined by the APTA (APTA 2003). A secondary goal was to describe the “lived experience” of Mentors serving in this program to understand the impact it had on the educational progression of the Mentors.

Materials and Methods

Mentee Participants and Location

Between 2016 and 2018 five classes of 5th grade students at a public elementary school in the Midwest participated as mentees in the Anatomy Academy program. This elementary school is an English and Spanish Dual Language Specialty School with a student body demographic that has a high enrollment of minorities and of low-income families.

Mentor participants

First and second-year graduate students in the DPT program at a small, private university in the Midwest were invited to participate in this study as Mentors. Thirty-one graduate students participated as Mentors; 16 females and 15 males.

Procedures

Doctor of Physical Therapy students interested in participating in this program were asked to fill out an application, which was reviewed by the lead faculty member of the program. Students were selected from these applications and invited to attend an introductory training. During this training, expectations and responsibilities of being a Mentor were discussed and Mentors were asked to assign themselves into groups of two or three. These groups worked together throughout the program. A criminal background check form was signed and submitted for review. Each Mentor had to pass the criminal background check to comply with school district policy about who can enter the school and interact with the elementary students.

This project was approved by the institutional review board of the university (IRB numbers: 0007-2017, 0003-2018), and informed consent was obtained from all Mentors during the introductory training.

The Anatomy Academy program consisted of a six-week schedule that included a weekly group meeting for all Mentors to review the upcoming curriculum and to delegate shared responsibilities. Individual mentoring groups were then asked to develop a lesson plan for the upcoming teaching session. Lesson plans focused on the following organ systems: musculoskeletal, cardiovascular, respiratory, digestive, and nervous. The six teaching sessions occurred in the classrooms, gym, and playground of the public elementary school. These weekly, one hour sessions included a five minute introduction to the new material with the entire class followed by a 25 minute active learning session in small groups. The small groups consisted of two Mentors and six to eight Mentees. The small groups participated in a 20-minute kinesthetic activity, followed by a ten-minute recap of the learning experience with the whole class. The training, curriculum, and assessment for the Anatomy Academy program is described by Diaz M et al. (2019) and this short online video demonstrates interactions between the Mentors and the Mentees during a teaching session (https://education.byu.edu/cites/initiatives/anatomy.html).

Data collection

Mentors were asked after each teaching session to respond to prompts or questions and reflect on their experience. The reflective writings were submitted, confidentially, as a survey using the learning management system, Brightspace (D2L Corporation, Kitchener, ON, Canada). These responses were then downloaded and analyzed by the researchers. A table with the prompts and questions is found in Appendix 1.

Data Analysis

Descriptive phenomenological methods were used. The written reflections provided descriptions of the lived experiences texts of the DPT students participating as Mentors. Reflections were analyzed by the whole-parts-whole method outlined by Giorgi (1975, 1997). Four researchers independently analyzed the written reflections for common themes. This analysis included taking on an attitude of phenomenological reduction as researchers independently sought for precise meaning in the Mentors’ reflections. Researchers independently described the Mentors’ experience as themes emerged through this analysis. This approach included collecting written data from
the Mentors and then reading the data multiple times. The researches then separated the data into meaningful parts using phenomenological reduction, which was followed by organizing and expressing the data within the researchers’ disciplinary perspective. The data was summarized in various themes and significant quotations were assigned to these themes as evidence (Giorgi 1975, 1997). These themes were sent to the lead author who compiled the themes to create unified emerging themes. The researchers then collaborated as a group to analyze the data together uncovering a few overarching themes and the emerging themes.

Results
It was apparent from this study that three central themes emerged from the data analysis. The overarching themes include: the ability to work with others, a personal awareness of self and society, and an understanding of the Mentors’ experience with the power of learning through real-world situations. This phenomenological study identified a common description of the overarching lived experience of the Mentors which transcended each Mentor’s individual experience. The following quotations were selected that provide evidence of these overarching themes.

The ability to work with others
Participant #20: I feel my interpersonal skills have expanded as I am able to teach and interact with younger students. I am typically used to interacting with others my age or older adults. I have felt an increase in self-confidence by sharing the knowledge I have learned in PT school with the students. The challenge with this has been finding appropriate ways to explain concepts to the kids so it is not overwhelming for the students. I also feel I have been able to expand my skills of collaboration through mentoring.

A personal awareness of self and society
Participant #24: Considering most of our student class was Hispanic, I would say my ability to recognize individual and cultural differences is increased. I notice differences most between the students and our mentors. We asked the students to try and complete some of the exercises we did in class with their siblings or parents at home, when one of them replied ‘my mom isn’t home at night, she works’. I don’t know the personal history of all the mentors, but I can assume that most of us didn’t grow up in a household where our parents worked overnight shifts. We had social engagement time with our parents, which might be why we are doctoral level students. We had drive and determination instilled in us from those experiences with our siblings and parents at home or on teams with our parents cheering us on. Not all of the students have that same sense in their homes.

An understanding of the power of learning in a real-world situation
Participant #13: Mentoring has provided me the opportunity to apply scientific concepts learned and understood in the classroom to real world issues by teaching them to real people in real learning environments. For example, today we taught the anatomy and function of the lungs to the students. We were able to help the students connect the scientific concepts of the lungs, specifically the flow of air through its anatomical structures, with real world issues such as how people contribute to unhealthy lungs, specifically through first-hand and second-hand effects of smoking, and how some people have diseases that obstruct or restrict airflow, such as asthma. Explaining these things is one thing, but demonstrating them so that people can have some sort of connecting or empathetic experiences really drives home the connection. We had students breathe through straws during some aerobic exercises. This exercise physically and visually showed students how difficult breathing can become when airflow is restricted, regardless the reason why.

The three emerging themes from the data analysis that Mentors shared as a lived experience include: critical thinking, interpersonal skills, and rethinking teaching and learning. Quotations were selected that provide evidence of these emerging themes.

Critical thinking
Participant #9: I’ve realized that everything isn’t just black and white. For example, it’s easy for us to say that smoking is bad for you. There’s research behind that, and it can visually be seen in pictures of the lungs. On the other hand, most people, regardless of their education, know that smoking isn’t good for them. One of the kids asked why people still smoked if they knew it was harmful. This brought up a good point that sometimes addiction is more powerful than science.

Interpersonal skills
Participant #12: Mentoring gives me the opportunity to actively listen to the students when they are answering questions regarding the material we are teaching them. Understanding the material at hand and speaking about it is one thing, but having the ability to assess whether or not students are comprehending what is being taught to them, can be challenging. As a mentor, I try to phrase questions with the appropriate level vocabulary. I listen to their responses and make sure I’m understanding their responses by asking follow up questions or asking them to draw out what they are saying. So far, we have seen success with the students being able to understand and retain information we have taught them. I think this can be attributed to our ability to be concise communicators, explicit explainers, and active listeners.

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Rethinking teaching and learning
Participant #27: However, I think that my ability to educate in these areas has improved, and I have learned how to teach these on a more basic level. For example, when teaching the students about the cardiopulmonary system it was more simple to discuss red and blue blood as a way to help them understand the difference between oxygenated vs non-oxygenated blood. Although the blood is not actually red and blue, this helped them to better visualize the flow of blood through the heart, lungs, and rest of the body.

Discussion
Much of the past literature on service-learning programs has focused on the effect on the Mentee (Cox 2005; Evans 2005; Schmidt et al. 2004). This research project focused on the benefits to DPT students that were willing to be a Mentor to elementary students within the service-learning program, Anatomy Academy. Few research projects have focused on a graduate student population (Lu and Lambright 2010), nor has a study related the results of a service-learning experience to the core values of professionalism in physical therapy. There are also few teaching opportunities for preclinical health care professionals (Diaz et al. 2019), let alone research that has studied the effect of these teaching experiences.

A phenomenological analysis (Giorgi 1975, 1997; Spinelli 1989; Van Manen 1990; Moran 2000) was used to understand the experience the DPT students had in the Anatomy Academy program. This research technique has not been commonly used in the understanding of service-learning programs and brings a new perspective in understanding the impact a service-learning program has on the life of a graduate student. The phenomenological process provided thick, rich descriptions of the experience of engaging in Anatomy Academy.

The purpose of our research was to describe the meaning of the Mentors’ experience with Anatomy Academy. This would lead to an understanding of the benefits in participating in this service-learning program as a DPT student and determine its value. A part of professional behavior is to self-reflect on one’s abilities and skills to determine strengths and areas of improvement. In addition, it is important for professionals to analyze real-life situations in context to determine appropriate and meaningful ways to educate and to treat patients. Anatomy Academy provided the structure for DPT students to self-reflect and to analyze real-life situations that provided insight into the value of this service-learning experience.

As Mentors critically reflected on what they were doing in the program and the purpose, they recognized the importance their actions had in influencing the Students. Mentors also realized they needed to develop their interpersonal skills to work more effectively with other Mentors and the Students in performing the tasks of this program. Teaching was also done in a classroom setting in small groups, which challenged the Mentors to learn and practice various teaching methods. As Mentors progressed through the program, they were able to reflect on their strengths and weaknesses. Many Mentors had their eyes opened to see themselves and the community that they were currently living in more clearly as displayed by their reflections.

These processes of learning by doing, learning by experience, and learning by self-reflection were all a part of the Mentors’ lived experience of Anatomy Academy. All are highly impactful lessons learned from this service-learning experience. Participating in the Anatomy Academy program gave the Mentors opportunities they did not expect in developing critical thinking, interpersonal skills, and teaching and learning that have been reported in other studies (e.g. Schmidt et al. 2004; Reynolds 2005; Simons and Cleary 2006; Kafai et al. 2008; Diaz et al. 2019).

The lived experiences of the Mentors indicated that they benefited from being a Mentor as they enhanced their critical thinking, interpersonal skills, and rethought teaching and learning. A few important categories revealed evidence of critical thinking. The Mentor’s progression as a learner was enhanced as they differentiated between important and true information, and what information may not be as critical to present. This process of distinguishing between types of information was applied to their weekly lesson preparation and teaching the Students.

Another category of critical thinking was developing the ability to infer their experience in the Anatomy Academy program to future clinical settings and to theorize that what they were doing in the program was helping them become better health care professionals. And lastly, Mentors experienced increased awareness of their own progression and of things that they did not anticipate was valuable to their personal growth. As future health care professionals, critical thinking is not only beneficial to their success in the profession but their ability to adapt to new situations and interact with patients.

Interpersonal skills are also crucial in developing a relationship and trust with patients. Active listening was a category under the theme of interpersonal skills that was identified by the Mentors as they needed to understand the thoughts of the Students in order to respond appropriately and meaningfully. Communication skills were enhanced as Mentors were able to understand the importance of interpreting nonverbal cues, teaching at an appropriate level of understanding for their audience, and remaining patient.

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Confidence in the Mentor’s ability to communicate about health-related topics was developed, including the ability to answer the Student’s questions about the human body and nutrition. Compassion and social awareness were enhanced as communication between Mentors and Students increased through a developed trust in their relationship. Mentors expressed their care and devotion to the Students, as if their sessions were not only about presenting information but more importantly about influencing the Students to make life-altering changes that would benefit themselves and their families. One challenge was for the Mentors to realize that each Student was living in different situations, and generally very different from the home life that the Mentor experienced. However, from this, Mentors were able to develop compassion and have a richer understanding of social injustice and how this awareness can help with current issues that we are facing within our country.

As future physical therapists, these Mentors will become teachers as they instruct and motivate future patients (APTA Academy of Education 2020). The emerging theme of rethinking teaching and learning appears to be a valuable awareness that the DPT students were able to experience and refine. A category that exemplified this development included the ability to manage the Student’s attention and help them focus on the lesson being introduced during that session. These experiences caused Mentors to reflect on teaching methods that were most effective. This reflection by the Mentors, in a role as a teacher, may be valuable for them to determine what type of teaching they would use as a health care professional.

As mentioned previously, Mentors realized that these sessions were not only about sharing information. They came to understand that they were to benefit the Student’s ability to make changes and that the process of learning could be fun and exciting. This development may have helped the Mentors to remember that through the many years of their own schooling, learning was enjoyable and that what they had learned could be applied to their professional development and be practiced in future clinical settings.

Regarding the core values of professionalism in physical therapy (APTA 2003), it appears that DPT students participating in the Anatomy Academy program developed these values. As Mentors, they took accountability of presenting weekly sessions to the Students and conducted themselves both with integrity and professionalism. Mentors did not receive course points or extra credit while participating in the program and they gave their time and talents willingly, which may have developed altruism. The core value of altruism may have made relationships with the Students more meaningful, which led to the development of compassion. Mentors developed excellence in critical thinking, interpersonal skills, and teaching. Developing these skills enhanced social awareness which is a beginning step in demonstrating social responsibility.

To summarize the lived experience, Mentors initially described anxiety with regard to interacting with the Students, but gained greater confidence in their ability to communicate and develop relationships with the Students over time. Mentors benefited as their teaching abilities improved, and their understanding of anatomy, physiology, and wellness deepened. It may be that the Mentors needed an opportunity to view these subjects in a different way and determine what part of these subjects were really important to share at a more basic level to 5th grade students. Mentors articulated the importance of their role in developing compassion for the Students and in developing a richer relationship with them. This compassion led to greater awareness of individual differences and social injustices that may assist Mentors’ involvement in their community to combat challenging issues faced by these Students regarding their health.

Limitations of this study include the following. The research project only focused on one DPT program situated in the Midwest, and only worked with elementary students from one school. Extending out to multiple programs and schools may give us a different or more robust understanding of a Mentors’ experience participating in the Anatomy Academy program as a DPT student. However, this analysis may have reached saturation in the reflective responses and additional Anatomy Academy programs would not reveal differences in the Mentor’s experience. In addition, we did not look at the perspective of the Students or the community partners (i.e. elementary teacher) in this study. A future study may note their reflections on the Mentors’ performance and determine if they correspond with the Mentors’ perspective.

The relevance of this study is that we are better able to understand the lived experiences DPT students had working with elementary students in a learning community setting, and how this experience may transfer in developing a more competent health care professional. In addition, DPT students may better understand how community educational programs may help personal growth, those they serve, and their local communities. These results may allow or encourage the establishment of early exposure to these programs in a DPT program or within other elementary school programs and communities.

**Conclusion**

Anatomy Academy is a service-learning program that provides Mentors an educational experience in a real-world setting and the opportunity to engage in the practice of teaching. This phenomenological analysis found that the program gives graduate students the opportunity to reflect on their past and present life experiences and use this reflection to become increasingly aware of themselves, their growth, and their
community. In addition, participating in this service-learning program prompts the graduate student to see themselves as a health care provider and visualize how this experience is helping them in their professional development.

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Literature Cited


APPENDIX 1: Prompts and questions for Mentors

**Week 1**
Prompt 1
Please answer the following reflection based upon your experience with Anatomy Academy. Please take a few minutes and reflect upon your experience before writing.

Question 1
How has being a Mentor influenced your ability to discern whether a statement about science (i.e., through media, or other source) is accurate or inaccurate? Please provide an example.

Question 2
How has being a Mentor influenced your ability to recognize individual and cultural differences? Please provide an example.

**Week 2**
Question 1
What methods did you employ to keep the attention of students while teaching Anatomy Academy principles?

Question 2
Has asking questions been an effective or ineffective tool for teaching children? Please explain your answer.

Question 3
How has mentoring influenced your ability to see the connection between scientific concepts and real world issues? Please provide an example.

Question 4
How has mentoring influenced your ability to actively listen to others? Please provide an example.

**Week 3**
Question 1
How has your basic understanding of anatomy, physiology, and nutrition concepts changed as a result of participating in Anatomy Academy? Please provide an example.

Question 2
How has mentoring influenced your ability to implement strategies to prevent and/or resolve conflict? Please provide an example.

**Week 4**
Question 1
How have your interpersonal skills changed as a result of participating in Anatomy Academy? Please provide an example.

Question 2
How has mentoring developed or enhanced your care and/or compassion for others? Please provide an example.
Week 5
Prompt 1
Share some of the comments or attitudes demonstrated by the elementary students in regards to their own habits as you taught them about the effects of diet, exercise, anatomy, and physiology.

Question 1
What were your impressions as you discovered the elementary student’s thoughts and attitudes about their own habits which influence diet, exercise, anatomy, and physiology?

Week 6
Prompt 1
Compare and contrast your feelings about working with elementary age children before Anatomy Academy and now.

Question 1
How has mentoring influenced your ability to promote health in the community?
Navigating in Darkness: Human Echolocation with Comments on Bat Echolocation

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Abstract
Echolocation is a type of biological sonar in which sound waves are emitted into the environment and reflected off objects to help organisms “see” the surrounding area. Echolocation is usually associated with bats and dolphins; however, some blind humans are able to adapt this technique to gain independence and freedom of movement in their environment. The most common noise emission human echolocators produce consists of mouth clicks made with their tongue against the hard palate. This article examines the history of echolocation in humans, the cues used by echolocators, the neural basis for human echolocation, and neuroplasticity associated with echolocation. It also provides relevant comments on bat echolocation. The material in this article would be useful in an academic setting to expand on the anatomical and physiological features of the eyes and ears, to illustrate neuroplasticity, and to foster a higher understanding of sensory processing capabilities. https://doi.org/10.21692/haps.2020.016

Key Words: echolocation, sonar, blindness, bat, neuroplasticity

Introduction
By the time he was 13 months old in 1967, Daniel Kish had lost both of his eyes to retinoblastoma. He might have lived a very sheltered life within the accepted parameters of his disability but, at the age of two, another life changing event occurred; he intuitively taught himself to make clicking noises with his tongue against his hard palate, in order to obtain feedback about his environment. These behaviors lead him to a lifelong study of echolocation, which enabled him to move with comparative freedom through his environment and eventually to teach others how to maximize this innate ability (Kish 2020).

Kish attended mainstream schools and has two Master’s degrees: one in psychology and one in special education. He started World Access for the Blind in 2002 and he is considered one of the foremost advocates and teachers of the blind. He represents many of the 39 million legally blind people in the world who wish for a more independent existence through self-reliance and determination (Kish, 2020; National Federation for the Blind (NFB), 2020). For some, a more independent existence may be attainable through the use of human echolocation, which offers the possibility that a blind person may be able to determine the size, shape, motion, location and distance of an object in their environment, and in some cases, even to determine the material from which an object is constructed (Milne et al. 2015).

Although the study of echolocation is a modern phenomenon, the origin of human echolocation dates back to 1749 when the French philosopher Denis Diderot theorized that the blind navigated by “facial vision”; the process of picking up information from the environment in the form of pressure waves generated by objects that were believed to form a pattern on a blind person’s face that could be “felt” and interpreted before a blind person bumped into an object such as a wall (Kish 2020; Kolarik et al. 2014).

It was not until the 1940’s and 1950’s that Karl Dallenbach’s laboratory at Cornell University established the existence of human echolocation by documenting that blind people were processing the echoes of their own sounds in order to keep track of their surroundings (Supa et al. 1944). Further research showed that both blind and sighted people who had normal hearing were able to successfully navigate their environment without vision (Thaler and Goodale 2016).

Donald Griffin, a Harvard physiologist, coined the term echolocation, as it pertains to bats, in 1944. Human sounds associated with echolocation e.g., tongue clicks, cane tapping, footsteps, and whistles, occur within the normal human hearing range of 20 to 20,000 Hz (Thaler and Goodale 2016). The clicks generated by the tongue against the hard palate of the echocator are usually very short, in the range of 3-15 milliseconds (ms), with a frequency of 3-8 kilohertz (kHz). Sound levels are typically in the 60 to 108 decibel range (Thaler et al. 2011; Thaler and Goodale 2016; Kolarik et al. 2014). Movements of the head and body, particularly swinging the head from side to side, are typical of human echolocation. Side to side movement of the head is reminiscent of bat behavior in which bats are believed to steer their sonar from place to place as a means of sampling their environment (Thaler and Goodale 2016). (See below for bat echolocation.)
Every human echolocation experience begins with the production of a particular sound made by the echolocator e.g., tongue clicks, cane tapping, or whistles. At some point, the echolocator hears the generated sound merge with its accompanying echo; or, for very short sounds, the echolocator is able to discern the generated sound accompanied by a silent gap. Finally, the echolocator perceives only the echo (Thaler and Goodale 2016). It is the analysis of these three consecutive elements of sound that provides the echolocator with the means of learning about the environment.

Experimentation in human echolocation is a developing area of science and it is spurring research in neuroscience and psychology, especially in the areas of neuroplasticity, the ability of the brain to rewire itself, and the processing of sensory information (Thaler and Goodale 2016).

This article outlines the history of human echolocation, identifies the most common clues used by echolocators, and examines the plasticity of the neural pathways that regulate this process. It also explores some of the similarities between human echolocation and echolocation as it is expressed in bats.

**Cues commonly used in human echolocation**

There are at least five acoustic cues that are used by humans to facilitate echolocation. Echolocators are initially cognizant of the relative loudness of noise in their environment, which is the result of the amplitude of the sound waves reaching the ear. They become conscious of objects in the environment because objects disrupt the normal patterns of auditory feedback; this is discerned as a disruption in the expected reverberation patterns in the surrounding area. Blind individuals are also attuned to the time delay that typically occurs between the production of sound and the start of an echo. When objects are far away, the time delay between the generation of clicks and the echo of the clicks is increased (Kolarik et al. 2014; Thaler and Goodale 2016).

The degree to which constructive and destructive interference interact with the returning echo enables echolocators to determine the pitch of the sound. A perceived change in pitch reportedly helps echolocators distinguish the composition of objects such as wood, carpet, plexiglass or fabric (Kolarik et al. 2014; Thaler and Goodale 2016). In the use of cues related to object distance, echolocators often report that there is a rise in the pitch of white noise generated by echoes as an object is approached, while loudness as a variable may remain unchanged (Kolarik et al. 2014; Thaler and Goodale 2016).

The direction of the sound can also be distinguished. For example, if an object is located to the right side of the echolocator, the noise will be loudest in the right ear. Echoes will be equally strong in the right and left ear if the object is located straight ahead (Kolarik et al. 2014; Thaler and Goodale 2016).

Of the over 1400 species of bats that live in the world, 86% use echolocation to communicate with each other, navigate, and find food in the dark. (depositphotos.com)
There is a correlation between the accuracy of human echolocation and the distance of an object that is greatest if the object is less that 12” away. Accuracy in locating objects decreases when objects are more that 24” away. When objects are located more than two meters away from the echolocator, the ability to pinpoint an object in the environment is no greater than chance for both sighted (blindfolded) and blind echolocators (Kolarik et al. 2014).

A strong correlation exists between the age at which a person became blind and the accuracy of echolocation achieved by that person. This may be related to practice or to a combination of practice and brain plasticity (See below for brain plasticity.) (Kolarik et al. 2014; Thaler and Goodale 2016).

It is expected that there are other acoustic clues used by individual echolocators since the range of experience and competency in individuals in this group is vast and there are numerous variations among individual behaviors.

**Neural basis for human echolocation**

Neuroimaging, such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), has provided much of the information about brain activity during human echolocation. Brain activity, as visualized with neuroimaging, is measured as blood oxygen level dependent (BOLD) activity, which tracks increased hemodynamic movement in specific areas of the brain (Arnott et al. 2013).

The first neuroimaging studies related to human echolocation were PET scans that were done by DeVolder et al. in 1999 to measure brain activity in blind and sighted individuals who were using a sensory substitution device while attempting to locate objects in their environment. The sensory substitution device used in this experiment was a prosthesis that consisted of a pair of glasses equipped with three ultrasonic transducers to generate sound and two earphones to pick up the echoes. This study determined that there was an increase in brain activity in blind people localized in the visual cortex in Brodmann area (BA) 17/18 during this exercise (DeVolder et al. 1999; Thaler et al. 2011; Thaler and Goodale 2016).

Subsequent studies conducted on blind echolocators by Thaler and Goodale (2016) confirmed significant increases in BOLD activity in BA 17/18 and also reported that the increase was strongest for echoes coming from the space contralateral to the hemisphere exhibiting the increased activity (Thaler and Goodale 2016). When brain activity was recorded from echoes coming back from moving objects, Thaler and Goodale (2016) observed that brain activity appeared to be increased in blind individuals in the temporal occipital cortex near what is known as the visual motion area, TM+, in sighted people. Echoes coming from the contralateral space again showed the greatest increase in activity (Thaler and Goodale 2016).

More research is needed to determine the significance of the strength of echoes coming from the contralateral space.

In sighted individuals, brain regions involved in the perception of visual form, the shape of objects, are located in the lateral occipital cortex (LOC), specifically in the inferior temporal and occipital-temporal regions of the brain. Tactile perception is also associated with these regions in sighted and non-sighted people (Arnott et al. 2013; Milne et al. 2015).

Brain regions associated with the localization of objects in sighted people include the occipital cortex, the precuneus (an area of the superior parietal lobe) and the posterior region of the parietal lobe. Localization of auditory sensations typically shows increased BOLD activity in the inferior parietal lobe, the posterior superior temporal sulcus and the superior frontal sulcus (Arnott et al. 2013; Milne et al. 2015). In the blind, the localization of sound also activates dorsal regions of the occipital cortex.

Determining the composition of an object’s exterior surface, whether it is hard or soft / metal or glass, shows increased BOLD activity in medial ventral brain regions, specifically in the collateral sulcus, the interior occipital gyrus, and the posterior parahippocampal cortex (PHC), including the parahippocampal gyrus and the fusiform gyrus (Arnott et al. 2013; Milne et al. 2015).

**Sensory advantage with higher frequency noise**

Norman and Thaler (2018) performed the first experiment to directly test whether there are sensory advantages when using higher frequencies in echolocation. Their study was designed to determine if blind participants who emitted sounds, either clicks or noise, could determine if an object was present at 1m, 2m, or 3m, or absent. This study determined that there was an increase in noise sensitivity when the frequency of both types of emission (clicks or noise) was increased from 3.5 to 4.0 kHz and provided evidence that higher frequency is associated with increased accuracy in echolocation performance (Norman and Thaler 2018).

The Norman and Thaler (2018) study allowed all participants to benefit from the use of higher spectral frequency. Emissions with peak frequencies between 3.5 and 4.5 kHz are in the range of human hearing, making the data from this experiment ecologically relevant. To ensure that these frequencies would pertain to everyday life, the metal object participants were trying to locate was the size of an item a person might encounter in their every day environment, for example, a large tree, or a person. Norman and Thaler (2018) determined that higher frequency emissions improved echolocation performance for object-detection tasks for both click and noise emissions and for all distances.

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Neuroplasticity

Neuroplasticity, the ability of the brain to adapt and change throughout life in response to environmental stimuli such as injuries, neurological diseases, and activity, is known to induce synaptogenesis and neurogenesis; under certain circumstances, it can enhance or restore neuronal functions such as memory, motor function, and cognition (Sasmita et al. 2018). Neuroplasticity is also evidenced when the brain rewires itself following the loss of one of the senses (Kolarik et al. 2014).

In a series of experiments, Arnott et al. (2010) found that when blind people process the shape of objects from echoes there is an increase in BOLD activity in the anterior and lateral regions of the occipital cortex as well as in the primary occipital cortex, areas that are associated with shape determination in sighted people. This suggests that when blind people determine an object's shape from echoes, regions of the occipital cortex traditionally associated with the processing of visual shape in sighted individuals, are recruited. The pattern of BOLD activation in the occipital cortex of blind people supports the presence of an echo-derived representation of the object in the visual cortex, which appears to be dependent on the ability of the auditory cortex to process the echoes (Arnott et al. 2013; Milne et al. 2015).

Activation of the visual cortex has been observed in tactile and auditory processing centers of the brain in studies of both long and short-term visual deprivation (Thaler and Goodale 2016). There is also evidence that characteristically visual areas of the brain are involved in reading and interpreting Braille. Visual areas of the brain are also believed to be involved in the processing of spoken language (Thaler and Goodale 2016).

Current studies suggest that blindness can lead to the reorganization of brain tissue such that the occipital region of the brain is co-opted for echolocation (Kolarik et al. 2014). Milne et al. (2015), working with blind and sighted participants analyzing BOLD activity associated with the processing of sound stimuli as compared to silence, observed that all participants in the study showed increased BOLD activity in Heschl's gyrus, the area of the brain that contains the primary visual cortex. This supports the hypothesis that stimulation of auditory areas of the brain in blind people can activate brain regions that are known to be visual areas in sighted people (Milne et. al 2015).

Further evidence from human studies suggests that those who were born deaf experience increased brain activity in the auditory cortex when they are engaged in visual tasks (Finney et al. 2003; Nishimura et al. 1999). Using PET scans to measure BOLD activity, Nishimura et al. (1999) found that the superior regions of the temporal lobe, areas important for hearing and understanding spoken language, were activated by sign language in deaf participants.

Using Magnetoencephalography (MEG scan), Finnery et al. (2003), working with deaf and hearing individuals, observed evidence of visual activity in the auditory cortex of deaf, but not hearing, participants when they were presented with visual stimuli. This suggests that the removal of one sensory stimulus in humans may lead to neural reorganization of the remaining brain areas. The increase in BOLD activity in auditory areas of deaf people in response to non-auditory stimuli indicates that the brain regions usually associated with hearing may be activated by other sensory modalities (Finney et al. 2003; Nishimura et al. 1999).

Recruitment of brain areas in the blind and deaf for different functions is an area of intense study in brain plasticity and research supports the hypothesis that areas of the visual cortex may be recruited for auditory processing in human echolocation (Kolarik et al. 2014; Thaler and Goodale 2016).

Echolocation in bats

It was not until the late 1700’s that Italian biologist Lazzaro Spallanzani, based on a series of experiments, showed that bats did not rely on sight when navigating in darkness; however, he failed to find the reason or the sense that replaced the vision (Spallanzani and Vassalli 1794). Inspired by Spallanzani’s experiment, in which he covered or removed their eyes, Swiss physician Louis Jurine conducted a series of experiments and concluded that bats use sound to navigate in darkness (Peschier 1798).

Of the over 1400 species of bats that live in the world, only 86% use echolocation to communicate with each other, navigate, and find food in the dark. The other 14% of species use only their eyes to navigate. Most echolocating bats use their larynx to produce echolocating sounds; however, a few species produce a click with their tongues. Echolocating sounds are generally emitted through the mouth, but some species emit their echolocation sounds through their nostrils (Moss et al. 2011; Thiagavel et al. 2018; Simmons and Cirranello, 2020). Contrary to popular belief, bats use their vision to fly in addition to echolocating, especially when they travel long distances, but this comes at the cost of reduced acuity (Boonman et al. 2013). Bat echolocation sounds are mainly ultrasonic ranging from 20 to 250 kHz (Schmieder et al. 2010). Tongue-clicking or laryngeal echolocators adjust bat flight and their calls (time-frequency structure) according to the situation to maximize information return.

Bat echolocation has evolved over several millions of years resulting in several morphological key adaptations. For example, bats have enlarged cochlea, an enlarged paddle-like or bifurcated cranial tip on the stylohyal, an articulation between the stylohyal and tympanic bones, movable pinna, a high degree of ossification of the larynx, calcification of the cricothyroid muscle, and several smaller adaptations (Simmons et al. 2010; Telling et al. 2016).

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Similar to humans, bats need to register the outgoing signal in the brain with the returning echoes. The ears and brain cells of bats are adjusted to the frequencies of the sounds they emit and the echoes that result from them. In order to code for the direction and distance of objects, the cochlea of each inner ear independently analyzes the frequencies of sounds and registers their amplitudes and times of occurrence. There are several parameters (e.g., clutter, frequency, harmonics, strength, time, etc.) that work in conjunction to make the calls of each species unique; moreover, a single species could have several different types of calls (Fenton, 2013).

Echolocation in bats is a highly specialized behavior that has been “tuning” for millions of years. This is a highly complex trait; echolocation is not solely for the purpose of navigating the dark nor do bats rely only on it to fly (they can still see while flying). Bat echolocation is a well-researched topic (Adams and Pedersen, 2013), whereas human echolocation is still in need of further research (Thaler and Goodale, 2016). Because of that, we need to be cautious when making comparisons or parallels between bat and human echolocation.

Application

The information in this article could be used in the classroom to enhance the study of the anatomical and physiological features of the special senses. In the most basic type of related activity, a student can get a sense of what echolocation is about by wearing a blindfold and responding to clicking noises generated by designated classmates. Students with a greater interest in the process can learn to make the clicks themselves and respond to the clicks in order to navigate the classroom or home environment. This activity could also be done as an extended outdoor laboratory exercise that would engage students in an experiential sensory activity centered on the location and identification of objects in the environment.

Individual instructors can best determine how students might participate in an echolocation activity based on classroom space, the age and interest of students, and the class time available for such an activity. Creative teachers should have no difficulty designing and implementing targeted classroom activities. If time permits, activities might include a comparison of the anatomy of human and bat visual and auditory systems, designing an experimental protocol to determine if a blindfolded student becomes more successful with echolocation over time, and a discussion of the difficulties encountered by those who attempt to master echolocation. The material found in this article could also serve a window through which an instructor might mount an activity that stresses the importance of getting students to think about the non-typical roles of the special senses, the adaptations made possible by neuroplasticity, and the study of higher order sensory processing.

Conclusion

The advantages for blind people who use echolocation include greater mobility, the ability to navigate in complex environments, perhaps without a service dog or a cane, greater confidence, and more independence. All of these help blind individuals make their way more easily in the world. As research into human echolocation continues, it will add to our understanding of the principles of sensory processing and neuroplasticity. The hope is that the technological advances that grow out of this research may ultimately bring significant improvement to the lives of the visually impaired.

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Navigating in Darkness: Human Echolocation with Comments on Bat Echolocation


The Interaction of Regenerative Medicine and Physical Therapy: A Systematic Review

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Abstract
Pathologies affecting the central nervous system (CNS) leave patients with life-altering disabilities. Research demonstrates that regenerative medicine (RM) and physical therapy (PT) techniques can provide structural and functional improvements. However, there is limited research evaluating the combined approach. The purpose of this study was to evaluate the efficacy of using the combination of RM and PT and its impact on therapeutic outcomes for patients with CNS disorders. Using PUBMed and Google Scholar, a systematic review was conducted and ranked using the Oxford Levels of Evidence. We surmised that combination of RM and PT could facilitate treatment of CNS injuries. https://doi.org/10.21692/haps.2020.011

Key words: central nervous system, regenerative medicine, physical therapy, lesions, exercise

Introduction
Regenerative medicine (RM) is an emerging field that utilizes different technologies such as tissue engineering and cellular therapies. It aims to repair, replace, or regenerate human cells, tissues, or organs to restore loss of function from various causes including congenital defects, disease, trauma, and aging. The ability to regenerate functional tissues, that were previously believed to be permanently damaged, opens many doors to new approaches and treatments for a variety of diseases and pathologies. Regenerative medicine provides a biological avenue for the body to combat diseases and to ultimately heal itself (Ambrosio et al. 2010).

Platelet-rich plasma (PRP) is one example of regenerative medicine that is used to aid in rejuvenating and healing tissues in the body. PRP is a combination of cytokines, growth factors, leukocytes, and platelets often used to hasten the healing process in the form of a non-operative treatment (Kunze et al. 2019). A review of the literature indicates that the efficacy of PRP has not yet been substantially validated. Furthermore, it is important from a physiological standpoint, to note that the efficacy and suitability of PRP depend not only on the type of injuries but also on the characteristics of the tissue(s) affected.

Bone-marrow and adipose-derived mesenchymal stem cells (MSCs) are also commonly used for their natural ability to maintain homeostasis while migrating to areas of injured tissues. They can be stimulated to easily differentiate into new resident cells to replace those lost as a result of damage to tissues. The MSCs can initiate immunomodulatory processes as well as secrete factors to aid in initiating tissue repair. A plethora of research has been conducted regarding the use of regenerative medicine technologies including the creation and regeneration of skin, nerves, cartilage, bone, skeletal and cardiac muscle (Koh et al. 2015; Spasovski et al. 2018; Wong et al. 2013). However, like the PRP studies, the research on MSCs, regardless of type, lacks evidence from the literature. It is important from an anatomical and physiological perspective to understand the lineage of MSCs, their ability to differentiate, self-renew, and the specific growth factors that influence the cells.

Osteoarthritis is an excellent example to illustrate how regenerative medicine works. It is the most common chronic degenerative joint disorder characterized by the deterioration and destruction of articular cartilage within the affected joints. Consequently, this leads to degeneration of other tissues of the joint and eventually causes pain, loss of mobility, and loss of function. The currently available pharmaceutical treatments focus on treating the symptoms and not the degeneration of tissues occurring within the affected joint.

A joint replacement is the most common treatment that provides long term relief of the symptoms of osteoarthritis. However, despite their drawbacks, the use of PRP and MSCs may slow the progression or possibly reverse the destructive processes that accompany osteoarthritis. These regenerative techniques have shown positive results in the regeneration of cartilage and amelioration of symptoms in osteoarthritis (Koh et al. 2015; Spasovski et al. 2018; Wong et al. 2013). With further research, these regenerative techniques could potentially open the door to new possibilities to combat osteoarthritis.
This article aims to trigger a discussion not only among health care professionals (e.g., physicians, physical therapists, researchers, etc.) but also medical and allied health students at all levels of higher education. Within various clinical settings, patients are looking for the best treatment option. Health care providers are primarily concerned with the evaluation of the current research and offering honest and professional opinions about treatment options. Ultimately, the course of treatment is the patient’s decision guided by professional help.

However, students and practitioners, are often inundated with buzzwords and statistically significant research that only fits a certain demographic with very specific parameters. Therefore, from a learning experience, the goal of this article is to provide not only information related to regenerative medicine, stem cells, physical therapy, and exercise, but also to provide anatomy and physiology professors and students with a background capable of improving their ability to evaluate research for the benefit of their future clinical practice.

Research Gap and Problem Statement
The research gap within our study first became noticeable when moving from bone disorders into nervous system disorders. Although regenerative medicine has demonstrated quality results in a variety of pathological conditions, including osteoarthritis, there are limited studies that analyze the combination of regenerative medicine and physical therapy concerning nervous system disorders. Specifically, there is limited research focused on the combination of these two treatment methods in humans. Moreover, at times, research involving regenerative medicine techniques may be supported statistically without demonstrating improved functional outcomes. Therefore, it is imperative for students and health care professionals worldwide, to understand these areas of research and discern the subtle differences.

Furthermore, available research demonstrates positive outcomes that support the merging of RM and PT into the concept of regenerative rehabilitation (Ambrosio et al. 2010). As of 2010, the American Physical Therapy Association (APTA) created the Frontiers in Research, Science, and Technology (FIRST) Council, intending to increase awareness of RM and whether physical therapists can increase success rates of therapy by using it (APTA 2017). However, there has been a limited amount of high-quality research that differentiates between the outcomes of combination versus isolated treatment.

Exercise alone is known to have healing effects when it comes to damaged tissue (Larson and Dension 2013). In animal models where rats were subjected to surgically induced strokes, exercise was shown to increase endogenous neural stem cell proliferation and differentiation (Liu et al. 2018). These types of results show promise in activating the body’s natural stem cell activity. Furthermore, Sasaki et al. (2016) showed that intravenous infusion of MSCs with 20 minutes of aerobic exercise on a treadmill provided a greater effect at reducing lesion volume size and increasing both synaptogenesis and functional movement when compared to infusion of MSCs or exercise alone.

Despite that, many of the exercise protocols are poorly defined. Also, our current literature review displays limited knowledge as to what type of exercise best supplements the treatment of pathologies with regenerative techniques. Shalaby et al. (2012) examined the effects of aerobic versus anaerobic exercise on stem cell activity and showed that hematopoietic stem cells displayed a statistically significant increase using the anaerobic exercise protocol versus aerobic exercise.

The effect of exercise on native stem cells, cell proliferation, and differentiation is an important foundation of both physical therapy and regenerative medicine. Likewise, different types of exercise can influence stem cell maturation and create a hospitable and optimal microenvironment for repair. Differences in the physiological effects of aerobic and anaerobic exercises are just one example of reasons for the research gap between these two powerful disciplines. Further issues are due to a lack of mutual understanding of key concepts and failure of creating a multidisciplinary approach to patient care and protocol development. Therefore, it appears that there is a disconnect between research across professions that enhance the improvement of a patient’s structural and functional restoration.

As the field of regenerative medicine grows, other healthcare professionals will need to be able to integrate these new approaches into their treatment methods. This is especially important in the field of physical therapy, where the main goal (to improve the individual’s function) is often limited by deficits such as degeneration of cartilage, loss of innervation and muscle wasting, or atrophy. In addition to working with patients with functional deficits due to musculoskeletal causes, physical therapists also provide rehabilitation to people with neurological disorders or injuries. The utilization of this new intervention of combining RM with PT in treating central nervous system (CNS) disorders has not been explored extensively (Huebner and Strittmatter 2009).

Most pathological conditions involving the CNS do not have many promising treatments due to the limited ability of CNS neurons for axon regeneration (Huebner and Strittmatter 2009). Injuries to the CNS, including spinal cord injuries (SCI), traumatic brain injuries (TBI), stroke, amyotrophic lateral sclerosis (ALS), and other injuries involving axonal disconnection, often leave the individual with an extremely limited possibility of recovery (Huebner and Strittmatter 2009). Incorporating PT rehabilitation programs with these RM
techniques could potentially lead to more successful results. Overall, the purpose of our study is to bridge the research gap of utilizing RM and PT interventions to treat central nervous system pathologies.

Theoretical Framework
The theoretical framework we developed was formed from researching the principles of RM techniques and PT for muscle and bone-related pathologies. We sought to determine whether there were similar outcomes using RM and PT when treating patients with CNS disorders, given the lack of self-regenerative capability of the CNS after injury. There is promising research in RM in its ability to promote repair of previously damaged structures and in PT that can help minimize deterioration and improve patient’s function after CNS injury (Ambrosio and Rando 2018; Mortiz and Ambrosio 2017; 149 Rando and Ambrosio 2018). However, there is limited information regarding a more beneficial effect of a combination of these therapies.

There could be several reasons for the lack of information about the effect of the combined use of RM and PT. Our approach to this systematic review was to lay out the best practices for central nervous system disorders with RM and PT. One way this can be accomplished is to start a discussion within anatomy and physiology curricula at both the undergraduate and graduate levels that will then progress into different disciplines including exercise physiology, nursing, nutrition, medicine, PT and research. Therefore, the information provided in this article is educational in terms of knowledge gained and in areas of developing further understanding in the classroom setting.

Ethics – Origin, and Use of Stem Cells
Harvesting stem cells from embryos gives rise to certain issues regarding the onset of human personhood and human reproduction. Debates about the status of human embryos have focused on whether the embryo should be treated as a person, or at the very least, a potential person. Importantly, researchers have been able to create pluripotent stem cells without the use of embryos. These are stem cells taken from somatic cells and transformed back into a stem-cell-like state of activity. These cells display the same pluripotent abilities of embryonic stem cells (ESCs) without the ethical dilemma.

The benefits of stem cell research include improved treatment and recovery from injury and disease as well as the provision of greater knowledge and understanding regarding human growth and cell development. This research can offer new methods of testing whenever new medical treatments are proposed to improve safety and reduce fatalities, as compared to performing trials on animals and humans, provide a chance to eradicate birth defects and mutations before they occur, and open the door to therapeutic cloning and RM (Lo and Parham 2009).

Methods
Data Sources and Searches
Research articles were identified using PubMed and Google Scholar databases. The literature review consisted of a three-pronged search approach using the keywords “Regenerative Medicine and Physical Therapy,” “Regenerative Medicine and Central Nervous System,” and “Regenerative Medicine, Central Nervous System, and Physical Therapy.”

Study Selection and Quality Assessment
Our inclusion criteria consisted of full-text peer-reviewed articles published in the last 15 years, written in the English language, involving animal and human subjects, level one to four clinical trials, and ranked one to four according to the Oxford Levels of Evidence as detailed in Table 1 from Oxford Centre for Evidence-Based Medicine (2009).

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The Centre for Evidence-Based Medicine
**Data Synthesis and Analysis**

A total of 3,557 articles were found. Of these, there were 68 articles that met the inclusion criteria and 54 that were included in the qualitative synthesis. The 68 articles that were initially screened displayed some type of involvement of either individual therapies or combination therapy among central nervous system pathologies. These articles were separated based on pathology and treatment type.

**Results**

The results for our systematic review were as follows (see Table 1): level 1 (5.6%), level 2a (1.9%), level 2b (7.4%), level 3b (29.6%), and level 4 (55.6%). The 54 articles included in the review met the inclusion criteria. Throughout our research, we analyzed different pathological conditions including ALS, SCI, cerebral palsy (CP), cerebrovascular accident (CVA), and traumatic brain injury (TBI). Furthermore, the articles were categorized and synthesized based on the area of focus. The areas of focus included animal and human studies, exercise, regenerative medicine, dual therapy, and cellular and molecular mechanisms such as autophagy and apoptosis.

The articles chosen were based on neurological pathologies and treatment using stem cells, exercise, or both. We believe that these two disciplines can promote better functional outcomes through movement/exercise. Physical therapists can incorporate their movement expertise to amplify the healing and repair of the central nervous system once the body is given the cells needed to produce these results.

**Discussion**

In this review, we focused on the management of the various pathological conditions that were evaluated by focusing on the application of either RM or PT technique alone, or a combination of both therapies. Moreover, the model examined different types of regenerative processes and different types of PT interventions that were selected from the literature. The different CNS pathologies are individually discussed below. It is important to identify the anatomical and physiological differences between types of pathologies, the treatment used, and how these treatments lead to improved function.

Amyotrophic Lateral Sclerosis (ALS)

The most notable finding of the review was that utilizing the treatment of stem cells via transplantation or intrathecal injections and/or exercise slowed the progression of the disease (Deda et al. 2009; Martinez et al. 2009; Oh et al. 2015; Sinelnyk et al. 2015). The type of exercise prescribed for this disease ranged from active cycle-ergometer at 60% manual power for 20 minutes, active exercises against gravity for three repetitive sets, and finally 20 minutes of passive ranged exercise.

The results of Deda, et al. (2009) showed not only a slowed progression of disease but also marked improvement in several different categories with only stem cell injections into the spinal cord. At the three-week follow-up visit, every patient displayed improvement in upper/lower extremity strength, swallowing, breathing, walking, head/neck control, talking, and improvements in both the bulbar and Norris scales. A slowing of the progression of the disease ultimately means the possibility of a longer survival rate, a significant finding in treatment possibilities for ALS. It would give patients more time to experience gains in therapeutic goals and stay functional for longer periods. These stem cell injection results coupled with skilled physical therapy such as that seen in Bello-Haas et al. (2007) and Lunetta et al. (2016), in which the authors employed resistance exercises or strictly modified exercise programs (SMEPs), could further improve scores using the Amyotrophic Lateral Sclerosis Functional Rating Scale (ALSFRS-R) that evaluates the functional status and change over time.

Likewise, Martinez et al. (2009) noted that the median survival time from diagnosis until the end of the trials of the treatment group (received transplantation of autologous CD133+ stem cells into the frontal motor cortex) was significantly increased (66 months compared to the control group (19 months). That gave patients on average 47 more months of function that can be improved by PT in an effort to improve the quality of life for these patients.

Spinal Cord Injury (SCI)

The most prevalent finding from the review was that utilizing RM techniques such as graphed stem cells can improve American Spinal Injury Association (ASIA) motor and sensory scores (Attar et al. 2011; Hur et al. 2016; Mendonca et al. 2014; Zhou et al. 2012). ASIA scores are used to describe functional impairments in terms of motor and sensory loss. The scale goes from A-E, where A is a complete loss and E is the normal motor and sensory. Therefore, an improvement in ASIA scores would be a trend toward the classification of E. We believe this is largely due to providing the body with the necessary materials to restore and repair damaged neural tissue. Furthermore, numerous articles display the importance of PT to improve muscle strength, endurance, coordination, and decreased body fat (Dobkin et al. 2006; Larson and Dension 2013; Sadeghi et al 2015; Theisen et al. 2017; Yang et al. 2014).

In addition to improvements in the ASIA score, Zhou et al. (2012) showed marked improvement in autonomic functions that impact urodynamics, such as increased ability to hold larger bladder volume and decreased residual urine volume. They were able to demonstrate that transplantation of autologous activated Schwann cells was both safe and partially effective. Likewise, Muniswami et al. (2018) explored whether bone marrow-derived mesenchymal stromal cells (BM-MSCs) were able to save injured neurons from death.
following an SCI. They demonstrated a switch from BM-MSC markers (CD54, CD29, CD73, CD90, and CD105) to instead expressing MAP2, NeuN, Beta-III tubulin, and NF after induction. These are mature neuron markers, further supporting reparative effects of stem cell treatment.

Concerning rehabilitation/exercise following a spinal cord injury, Yang et al. (2014) conducted a study comparing endurance treadmill walking versus a visually guided walking precision program. The results revealed that the endurance group exhibited significant improvements in distance, number of strides, and speed of their gait. Additional research is needed to support the claim, but this could be valuable information when creating a rehabilitation program for people who suffered from a spinal cord injury followed up by stem cell treatment.

**Cerebrovascular Accident (CVA)**

Persons who experience CVAs display impairments in motor, sensory, and function. However, a commonality between these patients is decreased quality of life and increased risk of mortality due to decreased muscle function, sensation, and coordination (Haacke et al. 2006; Rajkovic et al. 2018; NINDS 2014). People who are affected by a CVA are more likely have issues with energy, mobility, self-care, productivity, and social roles (Ramos-Lima et al. 2018). Younger patients display increased function after PT interventions likely due to neuroplasticity.

The current literature for combination RM and PT displays promising results in terms of decreased lesion size, improved in function, and increased cellular activation because of the materials provided, neuroprotective effects of exercise, and the training towards patient-specific function. However, most of the studies that are evaluating combination therapy as of 2019 are in animal models.

Two studies of Zhang et al. (2013 and 2014) demonstrated the neuroprotective effects that exercise has on strokes after a middle cerebral artery occlusion (MCAO). In both experiments, the animals were divided into an experimental group and control group. Each group underwent a MCAO using a standard and known process. Three groups in total were divided randomly into either the running group, the control group which did not exercise, and a sham-operation following an SCI. They demonstrated a switch from BM-MSC markers (CD54, CD29, CD73, CD90, and CD105) to instead expressing MAP2, NeuN, Beta-III tubulin, and NF after induction. These are mature neuron markers, further supporting reparative effects of stem cell treatment.

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Sasaki et al. (2016) and Liu et al. (2018) reported increased therapeutic effects of combination therapy, seen as statistically significant decreases in both volume of infarct and functional neurological assessment severity scores and increases in both synaptic and corpus callosum density.

Further studies are needed to determine if this mechanism works as well in humans. There would also need to be additional research into the best kind of stem cells to use and type of exercise to implement. This type of research could easily be implemented by incorporating physical therapy/therapists with expertise in neurology with medical groups already testing the use of stem cells on persons with a CVA.

**Traumatic Brain Injury (TBI)**

Currently, there is little research that met our criteria on the topic of utilizing RM and PT to treat people recovering from a TBI. The results of Cox et al. (2017) revealed that utilizing bone marrow mononuclear cells to treat severe traumatic brain injuries in adults was safe and feasible. Another study, conducted by Donega et al. (2013), explored the possibility of administering mesenchymal stem cells intranasally to treat neonatal hypoxic-ischemic (HI) brain damage in mice. The results indicated that the treatment could potentially become a promising non-invasive therapeutic tool to effectively reduce neonatal encephalopathy. This promising exploration of stem cell treatment in persons with TBI could further be enhanced not only by the neuroprotective effects of exercise on a stem cell treated nervous system but also in physical therapists’ ability to improve muscle function and coordination (Cox et al. 2017; Donega et al. 2013; Itoh et al. 2011; Lee et al. 2013).

**Cerebral Palsy (CP)**

Cerebral palsy is a developmental disorder that causes a permanent motor disability in children (Nguyen et al. 2018). Currently, the traditional treatments for cerebral palsy, which include botulinum toxin A injections and medications to relieve seizures and spasticity, have little effectiveness in addressing motor function and quality of life. Nguyen et al. (2018) investigated the effects of bone marrow mononuclear cell transplantation on the quality of life and motor tone and function of children with cerebral palsy with no emphasis on physical therapeutic interventions. The results of their study indicated that the quality of life, as well as gross motor function and muscle tone, were significantly improved six months after the bone marrow mononuclear cell transplantation.

Another study conducted by Sun et al. (2017), explored the effectiveness of administering autologous cord blood to improve the motor function in children with cerebral palsy. The participants who received autologous cord blood infusions while additionally receiving traditional physical therapy services showed the greatest improvements in their Gross Motor Function Measure-66 and Peabody

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Developmental Motor Scales-2 gross motor quotient scores. Traditional therapy includes interventions with an emphasis on improvement in muscle coordination, strength, endurance, and range of motion.

**Limitations**

Even though the field of regenerative rehabilitation is a rapidly growing area of study, there are numerous limitations in place. Money will always be a limiting factor in the realm of research and new advances in medicine. More specifically, clinical trial requirements provide a “bottle-neck” period to establish the safety of treatment in the general human population. Currently, the issue with clinical trials is the challenge of accepting participants that fulfill prerequisites. While it is true that there are plenty of people in the population who would volunteer to participate in a clinical trial, some study standards eliminate the number of applicants. For example, a study included in our review required participants to live within a commutable distance to an “autologous cord bank”; denying hundreds of potential applicants the opportunity to participate (Sun et al. 2017).

Physical therapy, in isolation, is considered an art as well as a science. An ethical physical therapist realizes that a patient’s treatment plan should be highly individualized, with few exceptions. Unfortunately, many of our reviews considered “treadmill running” to be the rehabilitation aspect of the authors’ study. Even though these studies were performed on rats, forced exercise still elicits a different physiological response than voluntary movement.

Also, some studies use “traditional physical therapy” as a control group comparison. However, the details as to what this therapy is comprised of were not mentioned or given a vague description such as, “leg endurance exercises.” Once relationships between variables, such as stem cell dosage, the timing of stem cell dosage, the timing of rehabilitation treatment, the energy system being utilized, the intensity of rehabilitation, comorbidities of participants, etc. become further established, the representation of combination therapy will become more transparent. A better understanding of the basic relationship that these variables share will augment the ability to treat special cases, such as using autologous stem cells on a patient containing a transplanted organ (Rando and Ambrosio 2018).

The multitude of these variables amplifies the need for a multidisciplinary approach to regenerative rehabilitation. Moritz and Ambrosio (2017) addressed this concept. They stated that, at the time of site access, there are almost 1300 studies involving “stem cell transplantation” or “tissue engineering” listed on the National Institutes of Health reporter. Only eight of these were housed in rehabilitation departments. This disconnect is further identified by the usage of general treadmill running or nondescript exercise in many of the reviewed articles. Better collaboration between rehabilitation specialists (physical therapists), physicians, and biologists will ensure the highest level of expertise, from each respective field, is being utilized in clinical trials and beyond.

Furthermore, with the ever-evolving patient-centered and holistic approach that health care is taking, there will be a larger emphasis on preventive medicine. Using lifestyle modifications, specifically exercise, as a form of treatment to prevent pathologies is just one example of preventative intervention. Therefore, it is important to understand how the exercise of different types influences our anatomical makeup and physiological characteristics. Many of these principles are relatively well known amongst exercise scientists and physical therapists. However, students beginning their journey within anatomy and physiology coursework and other professionals in higher-level courses need to delve into these concepts.

**Conclusion**

Overall, numerous research studies demonstrated the capacity of isolated RM or PT interventions to improve patient quality of life. These articles displayed the safety, efficacy, and importance of physiology restoration and return or improvement of function. What we lack in the literature are high-quality studies in humans investigating the significance of combination therapy. While evaluating animal studies and evaluating the research gap by comparing isolated studies we have determined that the best option for persons with central nervous system pathologies would be combination therapy. The two-fold problem could be better dealt with by using experts in the fields of both RM and PT. Regenerative medicine can provide essential cellular components while exercise augments the biological environment and helps to improve function. The overall aim of this combination treatment would be an improvement in patient function and quality of life.

Although further research is needed in this area, the combination of RM techniques and PT interventions has been deemed a safe and effective method for treating central nervous system lesions/injuries (Cox et al. 2017; Deda et al. 2009; Hur et al. 2016; Mendonca et al. 2014; Prabhakar et al. 2012). Using stem cells to treat central nervous system lesions has shown overall general improvements, such as decreased deterioration, increased strength, increased function, and increased morphological cell changes. Lower levels of evidence, regarding spinal cord lesion recovery, revealed that utilizing the combination of RM and PT improved ASIA scores (Attar et al. 2011; Theisen et al. 2017). Using exercise and rehabilitation to treat central nervous system disorders has shown overall general improvements including decreased deterioration, improvements in speed, and improvements in the distance traveled (Yang et al. 2014). Although there is a lot of research that included exercise or some form of rehabilitation in the treatment approach for CNS lesions,
there is an inadequate amount of information on the exercise principles (frequency, intensity, time, and type) included, making it difficult to draw conclusions or replicate the studies.

Finally, and most recently, research indicates that exercise can augment cellular and molecular mechanisms. Exercise demonstrates the ability to optimize the environment for RM techniques to either repair or restore natural components. Zhang et al. (2013) and Zhang et al. (2014) demonstrated the restorative properties of exercise in rats post-CVA. Exercise was able to decrease edema and necrosis after a MCAO and increase the Modified Neurological Severity Scores (MNSS). The future of these two professions shares a commonality. They aim to provide the best environment and components necessary for the most favorable and functional outcome possible. Future research will be able to evaluate clinical trials using RM and research studies that have better-defined exercise protocols.

Anatomy and physiology instructors at the collegiate level are in an ideal setting to include information related to physical therapy, exercise, RM, and central nervous system pathologies. These instructors can reach a broad range of students that will go on to specialize in many different settings and disciplines. This information can be included to enhance the basics of neuroanatomy and physiology, exercise science, and cellular development. Additionally, it can help complement current teaching to give a more practical and functional use of current education material utilized in the classroom.

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Literature Cited


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The Interaction of Regenerative Medicine and Physical Therapy: A Systematic Review


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.”

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The Use of CRISPR-Cas9 Gene Editing to Restore the Expression of Dystrophin in Models of Duchenne Muscular Dystrophy

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Abstract
Duchenne muscular dystrophy (DMD), characterized by progressive muscle degeneration, is a genetic disorder caused by mutations in the dystrophin gene. Recent studies using animal models have supported the potential of CRISPR-Cas9 gene editing to restore the expression of functional dystrophin protein in DMD. CRISPR-Cas9 treatment has been shown to improve dystrophin expression and muscle histology in mouse and canine models of DMD as well as human cells in vitro. Recent studies illustrate the importance of the dosage and delivery method of the CRISPR-Cas9 components in achieving optimal gene editing. The results represent a key step toward the future clinical use of CRISPR-Cas9 gene editing as a treatment for DMD and many other genetic diseases. https://doi.org/ 10.21692/haps.2020.018

Key Words: Duchenne muscular dystrophy, dystrophin, CRISPR-Cas9, gene editing

Introduction
Some of the newest and most interesting technologies at the forefront of genetic research give scientists the ability to change the DNA of an organism at the level of the cell nucleus. Known as genome or gene editing, this is a group of technologies that can add, remove, or alter targeted sections of DNA.

The first genome editing technologies, developed in the late 1900s, were time-consuming to use, expensive, and often unreliable (National Human Genome Research Institute 2019). CRISPR-Cas9, which stands for “clustered regularly interspaced short palindromic repeats” and “CRISPR-associated (Cas) nuclease (protein) 9” (Genetics Home Reference 2020), is one of the most recently developed genome editing technologies. The term palindromic sequence refers to a section of DNA or RNA that when read in a certain direction on one strand (either from the 5’ end to the 3’ end, or from the 3’ end to the 5’ end) matches the sequence on the complementary strand when it is read in the same direction.

Like many of the laboratory techniques that are used in biotechnology, the CRISPR-Cas9 system was developed after scientists discovered how bacteria had been editing their own genomes for billions of years. In self-defense, bacteria normally capture small sections of DNA from viruses that attempt to invade them. Bacteria use this captured viral DNA to create specific DNA segments known as CRISPR arrays. The bacteria then use the CRISPR arrays as a means of remembering the virus if the same virus, or a closely related one, tries to invade the bacteria again. In response to a second viral attack, the bacteria are able to produce RNA segments from the CRISPR arrays. The RNA segments target incoming viral DNA, and bacteria use the Cas9 enzyme, or a similar enzyme, to cut apart the viral DNA and destroy it (Genetics Home Reference 2020).

The CRISPR-Cas9 system works the same way in the laboratory. Researchers create a small piece of RNA that has a short “guide” sequence attached to it. This is known as the sgRNA. The sgRNA is comprised of two parts: crispr RNA (crRNA), a 17-20-nucleotide sequence complementary to the target DNA, and a tracrRNA, which serves as a binding frame for the CRISPR-associated (Cas) nuclease (Jinek et al. 2012). The guide sequence binds to a targeted section of DNA in the genome of an experimental organism. The RNA also binds to the Cas9 enzyme. Just like bacteria in the wild, the laboratory constructed RNA recognizes the DNA sequence and the Cas9 enzyme cuts the targeted DNA. Once the DNA is cut, the cell’s own DNA repair system is used to add or delete DNA or to replace an existing section of DNA with a laboratory engineered DNA sequence (Figure 1) (Genetics Home Reference 2020; Jinek et al. 2012).

Figure 1. CRISPR-Cas9 gene editing. Once the sgRNA binds to a targeted section of DNA, the Cas9 enzyme is recruited to the location and cuts across both strands of the targeted DNA. After the targeted section of DNA is cut and removed, the cell’s own DNA repair mechanisms can be used to insert or delete DNA or replace the removed section of DNA with new genetic material (depositphotos.com).
Genome editing may eventually play a huge role in the prevention and treatment of diseases that have a basis in the genetic code, such as hemophilia, sickle cell anemia, cystic fibrosis, cancer, heart disease, and Duchenne muscular dystrophy. This article examines the potential use of CRISPR-Cas9 technology in the treatment of Duchenne muscular dystrophy and offers suggestions for applications of this technology in the classroom.

Duchenne Muscular Dystrophy

Duchenne muscular dystrophy (DMD) is a recessive X-linked genetic disorder marked by progressive muscle weakness resulting from mutations in the dystrophin gene (Genetic and Rare Diseases Information Center 2020). DMD primarily affects males and has a prevalence rate of one in every 3,500 live male births. This disorder presents in early childhood (three to five years of age) with symptoms such as proximal muscle weakness, enlarged calves, difficulty standing, and an unsteady gait. Larger than normal calf muscles are the result of fat deposits and connective tissue that replace muscle tissue as scar tissue builds up in the muscle. This results in an awkwardness of movement that is characteristic of people who have DMD (Mayo Clinic 2020; Sarepta Therapeutics 2019). This awkwardness may include needing help to get up from the floor, using the arms to “walk” the body to a standing position (the Gower movement), or walking on the toes and extending the stomach for balance. Other symptoms may include fatigue, delayed speech, and behavioral and learning difficulties (Mayo Clinic 2020; Muscular Dystrophy News 2020; Sarepta Therapeutics 2019). Individuals who have DMD are more likely to have attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and obsessive–compulsive disorder (OCD) (Sarepta Therapeutics 2019). One in three patients with DMD will have cognitive impairment accompanying these learning and social disorders (Genetic and Rare Diseases Information Center 2020). Scoliosis, related to the length of time spent in a wheelchair, is a common condition in people with DMD, as are contractures (tight or rigid joints) and limited range of motion in the extremities (Genetic and Rare Diseases Information Center 2020).

By 12 years of age, most affected males are wheelchair-bound. Many affected males will display abnormal cardiac functioning by age 18 as a result of cardiomyopathy, the wasting away of myocardial tissue. Cardiomyopathy makes it harder for the heart to pump blood to the rest of the body; this may result in an abnormal heartbeat that can progress to heart failure (Genetics and Rare Diseases Information Center 2020; Mayo Clinic 2020; Muscular Dystrophy News 2020). Progressive wasting of the diaphragm and breathing muscles can lead to an increased incidence of respiratory infection, which can progress to respiratory failure and perhaps the need to be sustained on a ventilator (Genetics and Rare Diseases Information Center 2020; Mayo Clinic 2020; Muscular Dystrophy News 2020). Individuals with DMD may die of cardiac and/or respiratory failure in their twenties or early thirties. Due to its common prevalence rate, progressive nature, and serious clinical symptoms, DMD is the most severe form of the nine types of muscular dystrophy (Sinha et al. 2017).

Dystrophin

Dystrophin (DMD) is the largest human gene, encompassing over two million base pairs and 79 exons. This gene is on the short (p) arm of the X chromosome between positions 21.2 and 21.1. The dystrophin gene encodes the cytoskeletal protein dystrophin, which is a major structural component of muscle, connecting the internal cytoskeleton to the extracellular matrix. The dystrophin protein also functions in cell signaling (Aartsma-Rus et al. 2006; Nowak and Davies 2004; Online Mendelian Inheritance in Man 2002).

Over 2,000 mutations have been discovered in the dystrophin gene of individuals with DMD and the less severe form, Becker muscular dystrophy. A majority of dystrophin mutations are extensive insertions or deletions of exons, which create frameshift mutations downstream in the gene. Other mutations associated with DMD are point mutations, small frameshift mutations, and nonsense mutations. These mutations can either alter the optimal functioning of dystrophin or prevent functional dystrophin protein from being produced (Aartsma-Rus et al. 2006; Nowak and Davies 2004). Many of these mutations are contained within a “hotspot” region of the DMD gene, which encompasses exons 45 to 53. Deletion of exon 50, resulting in a reading frame shift beginning with exon 51, is one of the most common deletion mutations in patients with DMD. The next most common mutation in the “hotspot” region of the DMD gene is deletion of exon 44, which disrupts the reading frame of DMD in surrounding exons (Amoasii et al. 2018; Min et al. 2019).

Animal Models of DMD

Animal models of DMD are important for studying the development of the disorder and providing a gateway to clinical trials. The muscular dystrophy X-linked (mdx) mouse and golden retriever muscular dystrophy (GRMD) dog are the two most common animal models of DMD (Bulfield et al. 1984; Kornegay et al. 1988). Other canine models, such as the Rottweiler, German short-haired pointer, and beagle, have also been used to study DMD (Partridge 1997; Schatzberg et al. 1999; Shimatsu et al. 2003). Additionally, feline models have been explored for use in DMD research. Hypertrophic feline muscular dystrophy (HFMD) is seen in cats with dystrophin deficiencies; however, HFMD cats are not commonly used as a model for DMD due to their limited phenotypic similarity to humans with DMD (Collins and Morgan 2003; Kohn et al. 1993). While dystrophin deficiencies have been identified and/or created in zebrafish and the roundworm Caenorhabditis elegans, these animals are rarely used as models for DMD (Baumeister and Ge 2002; Chamberlain and Benian 2000; Chambers et al. 2001). No primate models for DMD exist (Collins and Morgan 2003).

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DMD Treatment

There is currently no cure for DMD, but treatment can help reduce its symptoms. Corticosteroids, which work to reduce inflammation, help individuals with DMD by improving the function and strength of muscles, delaying the need for assisted ambulation, and increasing the time it takes for the development of conditions such as cardiomyopathy and scoliosis (Mah 2016; Yiu and Kornberg 2015). Routine cardiac magnetic resonance imaging (MRI) is typically used to monitor and detect early cardiac dysfunction in patients with DMD. Angiotensin-converting enzyme (ACE) inhibitors, which work by dilating the blood vessels and increasing blood flow, and beta-blockers, which reduce blood pressure, help to delay the progression of cardiomyopathy. Routine pulmonary testing is normally conducted to monitor and treat early respiratory dysfunction of DMD patients (Mah 2016). Respiratory support, such as the use of ventilators and cough assists, can help to improve the life expectancy and quality of life of patients with DMD (Mah 2016; Yiu and Kornberg 2015).

Several other therapies to treat DMD are being investigated in both animal models and humans with DMD. Among them are cell therapies such as myoblast transplantation and patient-derived induced pluripotent stem cell transfer (Asakura 2012; Briggs and Morgan 2013; Torrente et al. 2001), membrane stabilization, and upregulation of cytoskeletal proteins (Mah 2016; Nowak and Davies 2004). The upregulation of cytoskeletal proteins such as sarcospan, utrophin, integrin, α-7-β-1, and biglycan has stabilized the sarcolemma of muscle cells and prevented dystrophic development in mdx mice (Amenta et al. 2011; Heller et al. 2013; Mah 2016; Marshall et al. 2013; Nowak and Davies 2004; Tinsley et al. 2011). These treatments have had some degree of success but there is still a major medical need for new strategies that can correct the genetic mutations in the dystrophin gene that are the underlying cause of DMD (Min et al. 2019). Current research suggests CRISPR-Cas9 gene editing technology has promise for being able to accomplish this goal.

Recent Studies Have Promising Results

In a recent study, Amoasii et al. (2018) used CRISPR-Cas9 gene editing to restore the expression of dystrophin in a canine model of DMD. In a similar experiment, Min et al. (2019) used CRISPR-Cas9 gene editing to restore the expression of dystrophin in a mouse model of DMD that the researchers generated as part of the study. Both studies delivered the CRISPR-Cas9 gene editing components intramuscularly and systemically, either through intravenous or intraperitoneal injection.

Amoasii et al. (2018) used CRISPR-Cas9 gene editing in a canine model of DMD to correct a mutation in the dystrophin gene. Following the CRISPR-Cas9 treatment, the dogs were able to produce functional dystrophin protein. The researchers also observed improved muscle tissue structure in the treated canines. In this study, higher doses of the CRISPR-Cas9 components were more successful in treating the canines with DMD. Analysis of the skeletal muscles after systemic delivery of the CRISPR-Cas9 gene editing components showed dystrophin was restored to 3% to 90% of normal values, depending on the type of muscle receiving the treatment. In dogs receiving the highest doses of the gene editing components, dystrophin was restored to 92% of the normal expected levels in the heart (Amoasii 2018). The dogs that received this level of treatment also showed improved muscle histology. Large animal studies like this support the notion that further CRISPR-Cas9 development might produce a clinically useful treatment for DMD. Future studies would need to be conducted to determine an optimal dose for this type of gene editing treatment, as well as the long-term safety of the CRISPR-Cas9 approach.

In a similar study, Min et al. (2019) used CRISPR-Cas9 gene editing to correct a different mutation in the dystrophin gene in a mouse model of DMD. Following treatment, the researchers observed functional dystrophin protein production in the treated mice. The treated mice displayed improved muscle tissue structure, function, and strength. In this study, the researchers used two different sgRNAs in the CRISPR-Cas9 treatment, one of which was more successful than the other. This is important for future studies when considering how to design and test experimental procedures involving CRISPR-Cas9 treatment. The researchers used increasing ratios of the CRISPR-Cas9 components in the treatment of the mice and observed that higher doses achieved better results. This also suggests the need for future studies to determine an optimal dose for CRISPR-Cas9 treatment. While additional studies need to be conducted prior to use with humans, these results are promising for the future clinical use of CRISPR-Cas9 gene editing in the treatment of DMD.

Additionally, Min et al. (2019) were able to establish a new mouse model of DMD that lacks exon 44 of the dystrophin gene. This is significant because this area of the dystrophin gene is a prevalent hot spot for dystrophin mutations in humans. These mice displayed the hallmarks of DMD including the degeneration of muscle cells, fibrosis, fat deposits in the muscle tissue, and loss of contractile function. This achievement should provide a good model for further research. The researchers observed an approximate 90% restoration of dystrophin expression in all muscles of these mice, including the heart, four weeks after administration of the CRISPR-Cas9 gene editing materials. It is not yet known how long the effects from this treatment will last or if the effects on the muscle tissue will alter or fade over time (Min et al. 2019).
Classroom Application
Information in this article can be used to enhance student comprehension of muscle anatomy and muscle contraction related to HAPS Anatomy and Physiology Learning Outcomes:

Module D, Histology 4. Microscopic anatomy, location, and functional roles of muscle tissue.
1. Describe the structural characteristics common to all types of muscle tissue.
2. Classify different types of muscle tissue based on structural characteristics, functions, and locations in the body.
3. Identify examples of each type of muscle tissue.

1. Describe the organization of skeletal muscle, from cell (skeletal muscle fiber) to whole muscle.
2. Name the connective tissue layers that surround each skeletal muscle fiber, fascicle, entire muscle, and group of muscles and indicate the specific type of connective tissue that composes each of these layers.
3. Describe the components within a skeletal muscle fiber (e.g., sarcolemma, transverse [T] tubules, sarcoplasmic reticulum, myofibrils, thick [myosin] myofilaments, thin [actin] myofilaments, troponin, tropomyosin).

This article also specifically relates to HAPS Learning Outcomes, Module G, Muscular System 13. Predictions related to disruption of homeostasis.
1. Given a factor or situation (e.g., muscular dystrophy), predict the changes that could occur in the muscular system and the consequences of those changes (i.e., given a cause, state a possible effect).

The article directly mentions muscular dystrophy and discusses the symptoms and the resulting consequences of these symptoms as they relate to the changes in the muscular system, such as muscle degeneration and weakness, and the consequences of cardiomyopathy or respiratory failure, for example. CRISPR-Cas9 gene editing could be introduced, and discussions could be held to predict how gene editing treatment could improve these changes in the muscular system and in turn improve the consequences of this disorder.

Finally, this article could also be used to broaden student understanding of genetics and heredity related to:

1. Define epigenetics and explain the impact of environmental factors on gene expression.
2. Describe the role of sex chromosomes in sex determination and sex-linked Inheritance.

An understanding of CRISPR technology also lends itself to classroom discussions concerning ethical questions that scientists and medical personnel are likely to have to consider. For example:
1. Would it be permissible to use gene therapy on an embryo even though it is not possible to obtain informed consent from an embryo? Is getting consent from a parent all that is necessary?
2. What will happen if gene therapies turn out to be so expensive that only wealthy people can afford them? Would this worsen existing healthcare inequalities?
3. Would it be ethical to use DNA editing technologies to alter traits that are not directly concerned with the prevention or treatment of genetic diseases? Could these technologies be used to enhance athletic ability or increase height?
4. Should gene editing technologies be used to edit germ line cells?

Today there is a great deal of interest in the introduction of Course-Based Undergraduate Research Experiences (CUREs) into undergraduate curricula. Undergraduate students taking molecular biology often take laboratory-based courses that teach them how to perform the polymerase chain reaction (PCR), genomic and plasmid DNA extraction, plasmid design and construction, restriction digestion, primer design, and perhaps some of the techniques necessary to create transgenic organisms using model organisms such as Escherichia coli and Caenorhabditis elegans. These molecular techniques are valuable resources for undergraduates entering the biomedical or biotechnology workforce, and they also provide a preexisting framework that easily lends itself to instituting CRISPR-Cas9–based CUREs.

Conclusion
Overall, these studies support the possible future clinical application of CRISPR-Cas9 treatment for the correction of DMD. Clinical trials using CRISPR gene editing therapies are currently being conducted for the treatment of cancers, blood disorders, and eye disease (Henderson 2019; Saey 2019). The first CRISPR-Cas9 clinical trial in the United States is being used to treat multiple myeloma, melanoma, synovial sarcoma, and myxoid/round cell liposarcoma at the University of Pennsylvania (https://clinicaltrials.gov/ct2/show/study/NCT03399448). The first use of an ex vivo CRISPR-based therapy is being used in a clinical trial to treat the blood disorder β-thalassemia in the United Kingdom, United States, Germany, and Canada (https://clinicaltrials.gov/ct2/show/NCT03655678). A clinical trial using ex vivo CRISPR therapy to treat sickle cell disease is underway in the United States, Europe, and Canada (https://clinicaltrials.gov/ct2/show/NCT03745287). Finally, an in vivo CRISPR clinical trial is being
conducted in the United States to treat the eye disease Leber congenital amaurosis 10 (https://clinicaltrials.gov/ct2/show/NCT03872479). If these current clinical trials are successful, they could lead to possible future CRISPR clinical trials for diseases such as DMD, cystic fibrosis, and other genetic disorders (Henderson 2019; Saey 2019).

One of the biggest scientific breakthroughs in recent years is CRISPR gene editing technology. The introduction of CRISPR technology has led to a recent wave of scientific research, lending itself applicable to classroom discussions of current topics in science. Compared to other gene editing tools, CRISPR is more time-efficient, cost-effective, and precise, making this technology more accessible for use in laboratory-based courses, as well as undergraduate and graduate research. Teaching CRISPR introduces students to fields such as genomic engineering, biotechnology, and molecular biology, allowing students to have the opportunity to discover new interests and explore future careers in science. Instruction on CRISPR technology also calls attention to important ethical questions concerning gene editing and can promote engaging conversation regarding the use of these technologies. Public and scientific interest in gene editing makes CRISPR technology an exciting and relevant topic for instruction.

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The Use of CRISPR-Cas9 Gene Editing to Restore the Expression of Dystrophin in Models of Duchenne Muscular Dystrophy


Designing High Structure Courses to Promote Student Engagement

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Abstract
While there are many strategies for increasing the inclusiveness of anatomy and physiology courses, increasing course structure is a strategy that can not only close achievement gaps for first generation and underrepresented minority students, but also increase performance for all students. High structure courses are characterized by clear learning goals, regular in-class exercises that promote student participation, and frequent out-of-class assignments that promote practice and preparation. In this article we describe ways to increase the structure of your course design and the learning environment in both face-to-face and online courses. https://doi.org/10.21692/haps.2020.019

Key words: inclusive teaching, course structure

Introduction
Teaching inclusively means reaching students of diverse backgrounds and experiences with a focus on identifying and mitigating biases that create barriers or exclude students (Dewsbury and Brame 2019). By being mindful of the diversity of our students we can create environments where any student can find success. Inclusive teaching can help students feel welcome in our classrooms and institutions. Furthermore, it welcomes more diversity in our discipline. The makeup of our institutions continues to change. Fifty-six percent of US undergraduates are white, 19% report disabilities (U.S. Dept. of Education 2018) and at least 40% are first generation college students (U.S. Dept. of Education 2019). Therefore, we need to pay attention to creating environments and experiences that welcome all of our students to learn and achieve success.

While there are several ways to make your teaching more inclusive, we can reach more of our students, no matter their background, by developing high structure courses and learning spaces. The structure of a course is the set of activities and experiences you use to expose students to course material and encourage them to practice using it. An example of a low structure course would be one based on low-interaction lectures and few, high-stakes assessments. In a low-structure course we assume that students know how to work with the material both in and outside of class time. Students are provided with regular opportunities to practice working with course material in the form of preparatory assignments prior to class, engaging in-class activities (active learning), and regular low-stakes review or practice assignments (Freeman et al. 2011; Haak et al. 2011). Eddy and Hogan (2014) have defined high structure courses as those with both preparatory and review assignments at least once per week where student participation constitutes at least 40% of the class time. Many assignments and activities in structured courses are low stakes and guide student reading and studying. Students are assessed more frequently than in a traditional low structure course. In a structured course we provide clear learning goals for our students, which specify the information they need to know and what they should be able to do with it. More structure in a course reduces guess work and trial and error as students learn how to work with course material. This allows more students to be deeply involved in learning, including those who may not have optimal social support systems, students with disabilities, and shy students.

In a high structure course, we remove the assumption that students know how to work with the material both in and outside of class time. Students are provided with regular opportunities to practice working with course material in the form of preparatory assignments prior to class, engaging in-class activities (active learning), and regular low-stakes review or practice assignments (Freeman et al. 2011; Haak et al. 2011). Eddy and Hogan (2014) have defined high structure courses as those with both preparatory and review assignments at least once per week where student participation constitutes at least 40% of the class time. Many assignments and activities in structured courses are low stakes and guide student reading and studying. Students are assessed more frequently than in a traditional low structure course. In a structured course we provide clear learning goals for our students, which specify the information they need to know and what they should be able to do with it. More structure in a course reduces guess work and trial and error as students learn how to work with course material. This allows more students to be deeply involved in learning, including those who may not have optimal social support systems, students with disabilities, and shy students.

In the biological sciences increased structure is associated with improved performance for all students (Eddy and Hogan 2014; Freeman et al. 2011; Haak et al. 2011). Students in moderate to high structure courses use their textbook more frequently, do less cramming, and use more of their textbook (Seaton et al. 2014). Improvements in performance are especially notable for first generation students and underrepresented minorities, where high structure eliminates the achievement gap (Eddy and Hogan 2014; Haak et al. 2011). Many of the studies on Open Educational Resources or free textbook materials that report closing achievement gaps may be actually seeing the benefits of increased course structure that come with

continued on next page
course packages that include reading quizzes connected to texts (Fischer et al. 2015; Hilton et al. 2016). The evidence suggests that there is no harm to our well-prepared and high achieving students by boosting course structure, but it promotes significant gains for students traditionally affected by achievement gaps in the sciences.

Interestingly, despite gaps in STEM degree persistence (Chang et al. 2014) and course achievement (Haak et al. 2011), the self-reported study habits of undergraduate students do not differ between ethnic groups (Lopez et al. 2013; Rodriguez et al. 2018). Perhaps the social aspects of a structured course design and learning space are integral to closing the achievement gap. In a highly structured course all students have frequent opportunities to participate in the dialogue of the discipline. All students are invited to participate in class activities. If more students feel comfortable and included in the class, perhaps they will seek help when they need it, which first generation and non-white students may do less frequently (Jenkins et al. 2009). Structure may also foster a greater sense of community among the students. Students also work more effectively outside of the classroom, perhaps more often with their peers.

There seem to be two major themes in promoting the success of diverse students in higher education: changing the students and changing the system. Increasing the structure of our courses is a way that instructors can work to change the system. In this article we describe the elements of a high structure course and offer recommendations for increasing the inclusiveness of the learning environment in both traditional face-to-face classrooms and in asynchronous online teaching.

Designing a Structured Course

Structured courses can be characterized by those with clear and accessible learning goals and expectations, inclusive, in-class opportunities to work with course material (Eddy and Hogan 2014), and frequent activities to practice working with material outside of class (Eddy and Hogan 2014).

1. Clear learning outcomes

Learning outcomes provide a course framework for both you and your students. They lay out what you expect of your students and how they will be assessed (e.g. do they need to know a fact or be able to do something with a fact?). The learning outcomes are your guide to how you will deliver the course and the tools you give to students to promote their success. General learning outcomes for the course are provided in the course syllabus, but offering more specific guidance to students in the form of more detailed learning outcomes on a daily or weekly basis increases structure as it provides more specific expectations for students.

It is beneficial to spend time throughout the term training students in how to best use learning outcomes to guide their learning and preparation. In an sample of undergraduate biology students nearly 1/3 reported not using learning outcomes to prepare for an exam. Fewer than 5% used the learning outcomes to self-assess their learning (Osueke et al. 2018). Few students may know how to locate or recognize learning outcomes, and student perception of the objectives of the course can be quite different from what the instructor intends (Austin et al. 2019). Students may give up on using learning outcomes if they have an incorrect understanding of their utility in learning and self-assessment (Austin et al. 2019). However, there is alignment between the ways students are encouraged to use learning outcomes (by current and former instructors) and how they actually use them (Osueke et al. 2018). Therefore, it is important to model and encourage appropriate use of the learning outcomes, as it could have lasting effects on self-regulated learning. In a high-structure course, there is the opportunity to create activities that serve the dual purpose of practicing course material and training in the use of learning outcomes. For example, learning outcomes could serve as questions for a ticket out the door exercise, or for clicker questions, or students could be asked to generate potential exam questions based on their understanding of the learning outcomes.

2. Course activities

The activities you use in your structured course must be closely aligned with your learning outcomes. In backward course design we begin by identifying what we want students to accomplish, then choose suitable teaching methods to meet those goals. When developing a structured course, the teaching methods will not always be a traditional lecture. It may be helpful to think of it this way: for each learning outcome, what is the best preparation students could do in their own time in order to achieve it? Would they read the text and make notes, make tables and diagrams to summarize their reading, complete practice questions, etc.? Your task is to find ways to get students to do these things. These tasks will become your in-class and out of class activities.

As you plan your activities, you’ll want to be cognizant of the following: Who might be left out of the conversation or learning opportunities when I do X in my class? Identifying moments when you might lose students is the first step to remedying them. For example, you decide to do practice problems in class and then go over them as a group. Will all students have the opportunity to participate in the dialogue if you do this? Who may be left out? How can you structure the class discussion about the practice problems so that everyone has the chance to participate?
A. In class activities
In anatomy and physiology, in-class activities could fall into these three general categories: practice questions, organizing course material, and discovery activities.

Practice questions
Here, students complete questions for practice and to check their understanding. These also provide you as the instructor with timely feedback on student learning. A lecture can be broken up by brief periods of practice that are designed to allow all students to work with the lecture material. These can be placed at logical stopping points in the lecture (e.g. when you need to wrap up a concept and check understanding before moving on and adding to it). Strategies here may include think-pair-share, clicker questions, or a half-sheet problem set.

Organizing course material
Academics tend to be good at organizing their knowledge, and sometimes we assume that students show up to our courses with the same abilities. In anatomy and physiology, becoming overwhelmed with details can hinder student success. Taking the time to make your in-class activities also serve as opportunities to organize and summarize knowledge should help students in your course and perhaps in other courses. Students can be tasked with making a table to organize information they gained from lecture or readings. Summing up information with a simple graph or as a mathematical equation are also appropriate forms of this type of practice in anatomy and physiology. In this way students learn to and practice categorizing, summarizing, and simplifying course material in ways that make it less overwhelming to work with on their own. Examples of activities include making a table comparing the anatomy and physiology of smooth and skeletal muscle or drawing a graph that summarizes the relationship between venous return and cardiac output.

Discovery activities
In physiology, there are several general models that can serve as the basis for understanding many physiological systems (Modell 2000). For example, an understanding of the concept of mass flow provides the basis for students to understand pressure-flow relationships in the vascular system or capillary exchange. Therefore, in physiology there are many opportunities for students to draw on their prior knowledge to generate knowledge about a new concept. Several published activities have been particularly useful in teaching undergraduate physiology such as an exercise that allows students to derive the Frank-Starling Law of the heart based on predictions they make about stretch and recoil of a rubber band (Groh 2017). Applying the concept of mass flow to the vascular system is an important component of Malmquist’s set of activities on Flux, Gradient and Resistance (Malmquist 2017). When appropriately tailored to your course activities such as these can nearly eliminate traditional lecture on particular topics. These activities also promote the practice of the skill of transfer, applying prior knowledge to a new situation or context, which can be difficult for students in physiology (Goodman et al. 2018).

B. Out of class activities
Out of class work can be categorized into two broad categories: (1) formative and preparatory assessments or (2) summative and review assessments. Preparation assignments get students ready for what is to be discussed in class. These can include guided reading questions, quizzes to be completed before class, or graphic organizers to organize information from readings. A trend in higher education has been the use of automatically graded or adaptive learning online homework systems. Carnegie Mellon's Open Learning Initiative specializes in creating homework and quiz questions embedded in readings that give instant feedback to students. They estimate the learning benefit of their learn-by-doing activities to be six times the benefit of watching videos or reading alone (Koedinger et al. 2016).

Summative or review assessments may include a variety of methods, such as authentic assignments that mimic professional tasks (e.g. medical case studies), cumulative quizzes that draw from a larger pool of knowledge, or assignments that ask students to summarize or explain key topics. By asking our students to apply particular knowledge and skills in different ways and different contexts, we can reinforce the importance of the learning outcomes and promote transfer of knowledge (Wiggins 1998). Both formative and summative assessments provide practice and feedback with course material rather than simply an assessment of student learning. With frequent (e.g. weekly), lower stakes assignments and corresponding feedback both the instructor and student have more opportunities to better understand when learning is going well and when students are struggling. By continuing to emphasize learning outcomes throughout the course, we encourage students to be more analytical about why they are asked to do things, and make connections between the outcomes, readings, small performance tasks, and authentic skill application.

Box 1 outlines a sample course unit on membrane and action potentials. This could be a weekly structure in which students complete the pre-unit activities prior to class on Monday and the post-unit activities at the end of the week.
Structured and Inclusive Learning Environments

Students are necessarily asked to participate in class activities more often in a structured course as compared to a traditional didactic format. In developing structured undergraduate physiology courses, it has become clear that explaining your reasoning for your course format and activities goes a long way in student participation and success. For example, homework assignments do not assess learning as much as they provide practice and feedback on learning. Explain that your methods are backed by research and learning theory. For example, activities that require students to practice simpler component skills will help them achieve more complex learning outcomes (Ambrose et al. 2010). You may also simply emphasize that they will learn more by doing than watching or reading (Koedinger et al. 2016). Simple reminders that you want all of your students to succeed can also be powerful, as students may not hear that enough.

Providing students with adequate quiet time to think and write ideas during in-class activities has a powerful effect on encouraging student participation, particularly for students who usually keep quiet in class. In a study of college classrooms 81% of questions posed in class required higher-order thinking, but the average wait time between the questions and accepting a student response was only 2.25 seconds (Duell et al. 1992). Rowe (1974) found that increasing wait time to 3-5 seconds was associated with increases in the number of student responses, number of unsolicited responses, number of speculative responses, and a decrease in the number of students who fail to respond. Without adequate wait time it is likely that the questions you pose in class will only benefit the quickest, most experienced students.

During in-class activities one can monitor participation so that a few students do not dominate the conversation. In large classes it may be helpful to have a system to regulate participation in discussions, such as using index cards for responses or calling on group reporters (Penner 2018). In smaller classes a mental list of who has and has not contributed to the discussion should suffice. It is also important to monitor participation in the work that goes on in class. In small classes, visiting each group during an activity can stimulate participation or clear up questions that were barriers to progress. You may reach more students by varying the types of active learning activities you use in your course (Tanner 2013). There are many ways to represent and summarize information in anatomy and physiology. Activities can be based on diagrams, graphs, or mathematical equations, and varying which mode you use throughout the course can ensure that no student becomes frustrated because they are out of their comfort zone all the time.

Beyond the design of the course, the structure and organization of an online learning environment is important for including all of our students. In general, all course materials should be clearly organized in the learning management system so that students can locate course expectations, access all their course learning materials and tools, and know
how they will be assessed. Students should have links and directions on how to access multiple support structures including technical supports and academic tutoring supports. An orientation to the course and to the technology used should be included to make sure that the rigor of the course is the course material, not the technology or organization of the course.

It is good practice to divide course materials by unit, module, or other divisions. Each section should have clear learning outcomes, a task list, and criteria for success. Our most at risk learners may be the ones that depend on this clear structure the most. When adding additional formative assessments and assignments, it is good practice to set these up in a routine so that students can become accustomed to a pattern of typical assignments and due dates. By making sure that all directions are explicitly clear and including the criteria by which students will be assessed, good course design takes away the guesswork for students by setting clear targets connected to frequent assessment. A typical module should have learning objectives, task lists, readings, activities, and assessments all organized linearly so that students can work their way through the materials.

**Conclusions**

Designing structured courses provides a starting point for making higher education, particularly in the sciences, a more inclusive environment. It is not the same type of work as creating and delivering traditional didactic courses, but the payoffs include closing achievement gaps and welcoming more diversity to our disciplines. Furthermore, structured courses are a way of demonstrating care for students and sending the message that we want all to succeed.

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