Student Efficacy and Final Grades

Traditional vs. Gamified Response Systems

The Survival of the Physiologist Game

The Value of Traditional Lecture

Why Students Study Physiology

Innovative Use of Audience Response Systems

Plasticity in the Periaqueductal Gray (PAG) and Analgesia

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The HAPS-Educator, The Journal of the Human Anatomy and Physiology Society, aims to foster teaching excellence and pedagogical research in anatomy and physiology education. The journal publishes articles under three categories. Educational Research articles discuss pedagogical research projects supported by robust data. Perspectives on Teaching articles discuss a teaching philosophy or modality but do not require supporting data. Current Topics articles provide a state-of-the-art summary of a trending topic area relevant to anatomy and physiology educators. All submitted articles undergo peer-review. Educational Research articles will additionally be reviewed for the quality of the supporting data. All issues of the HAPS Educator are freely available, and individual articles are uploaded to the Life Science Teaching Resource Community (and link to https://www.lifescitrc.org/).

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An Investigation of Potential Correlations between Student Self-Efficacy, Mindset, and Demographics with Final Grades in a Community College Anatomy and Physiology I Course

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Abstract
Associations of mindset, self-efficacy, demographic, socioeconomic, and several other factors with course grades were quantified for students who took the first human anatomy and physiology (HAP) course at Jamestown Community College during the Fall 2017 semester. Mindset and self-efficacy were measured with self-report Likert-agreement response scales. Students reported high levels of growth mindset and self-efficacy at the beginning and end of the course. For mindset and self-efficacy, only post-course self-efficacy levels were statistically significantly associated with grades: an increase of one level in self-efficacy was associated with a 7.4% increase in course percent correct grades. Of the demographic, socioeconomic, and other factors examined, only gender was statistically significantly related to grades: females had course percent correct grades that were on average 7.2% higher than males. Results suggest interventions to improve self-efficacy and research that elucidates the gender achievement gap could improve grade performance in the first HAP course. https://doi10.21692/haps.2019.007

Key words: anatomy and physiology I, course grades, mindset, self-efficacy, gender

Introduction
The first human anatomy and physiology (HAP) course is a critical science gatekeeper course in the pathway of a large number of two- and four-year healthcare science degrees (HAPS 2013). Course attrition rates are high with roughly one-third or more of students who take the first HAP course in the United States and Canada receiving grades defined as unsuccessful or failing. That rate is equal to approximately 150,000 students per year in those two countries (Russell et al. 2016). As a first step towards understanding what impedes success in the course, in a previous study (Russell et al. 2016), factors associated with poor letter grade performance in the first HAP course at Jamestown Community College (JCC) were identified. In that report, variables most strongly associated with low letter grades were: 1) took and passed a remedial reading, writing, or math course, 2) repeated any college class, 3) lacked prior college credit, 4) was a first generation college student, and 5) was younger. Gultice et al. (2015) also reported that 1) younger age, 2) lower high school GPA, 3) lower number of quarter hours prior to the course, and 4) a lower average math placement score were associated with lower grades in the first HAP course. When considered together, these findings suggest students who are not successful in the first HAP course may lack foundational abilities and/or traits that support cognition and cognitive skills.
An Investigation of Potential Correlations between Student Self-Efficacy, Mindset, and Demographics with Final Grades in a Community College Anatomy and Physiology I Course


Non-cognitive factors most commonly and strongly associated with academic achievement include mindset (Costa and Faria 2018), self-efficacy (Artino 2012, Honicke and Broadbent 2016), and grit (Bazelaïs et al. 2018, Clark and Malecki 2019). Mindset is the belief that intelligence is either fixed and unchangeable, or malleable with the potential for growth. Originally, mindset was called implicit theories of intelligence with fixed mindset named entity theory and growth mindset referred to as incremental theory (Kajanaaho and Tirronen 2018). Cavanagh et al. (2018) examined the relationship between a growth mindset and final course percent correct grades in the first HAP course. In that study, growth mindset was not associated with grades although the authors reported growth mindset was related to engagement with active learning. Self-efficacy is the belief in one’s ability to perform a specific task (Bandura 1997). One study has examined the association of self-efficacy to course attrition in the first HAP course (Witt-Rose 2003). That study reported a highly significant positive relationship between total self-efficacy score and mid-term and final grades. Grit is the perseverance and passion for long-term goals (Duckworth 2016). Although the original intent of this study was to examine grit, and grit data were collected after students were surveyed, several studies were published which cast serious reservations on the validity of grit’s construct (Credè 2018, Credè et al., 2017, Schmidt et al. 2018, Vazsonyi et al. 2018). Given the strong possibility grit data are not representative of a valid psychological construct, meaningful discussion of grit results is challenging and potentially misleading. Given that, grit scores are not presented or analyzed in the main body of this paper. However, for documentation purposes, grit data are summarized in Appendix A.

Thus, due to the potential for non-cognitive factors to explain course attrition, the first two specific purposes of this study were to quantify in the first HAP course: 1) levels of mindset and self-efficacy at the beginning and end of the course and 2) associations of mindset and self-efficacy with final course percent correct grades. Because replication is critical to the generalizability of research findings, a third purpose was to re-examine in this study grade associations of demographic, socioeconomic, and other factors identified as statistically significant in the prior study at JCC (Russell et al. 2016).

Methods
Study Population
Part of the State University of New York (SUNY, https://www.suny.edu/), JCC (http://www.sunyjcc.edu) is a two year regional, open-access institution providing liberal arts transfer degree programs, career programs, community service, developmental education, and business and industry training. Two campuses (Jamestown and Olean, NY) and one center (North County in Dunkirk, NY) serve about 2500 students annually in southwestern New York and parts of northwestern Pennsylvania. The study population consisted of students who were matriculated at JCC and were enrolled in one of Ellen Lehning’s three BIO 2510, Anatomy & Physiology (A & P) I lecture sections during the Fall 2017 semester. At JCC, BIO 2510 is the first HAP course. The features of BIO 2510 at JCC are provided in Table 1. Demographic, socioeconomic, and other characteristics of the study population are presented in Table 3 after it is explained how the final study population was selected.
An Investigation of Potential Correlations between Student Self-Efficacy, Mindset, and Demographics with Final Grades in a Community College Anatomy and Physiology I Course

**Table 1. Characteristics of the first human anatomy and physiology course at Jamestown Community College Fall 2017.**

<table>
<thead>
<tr>
<th>Course Number and Title</th>
<th>BIO 2510, Anatomy &amp; Physiology I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Course Description</strong></td>
<td>This first of two sequential human anatomy and physiology courses is designed for students who have had little or no previous study of the body or the physical and chemical principles on which body structure and function is based. In this course, students will learn basic chemistry and physics, cytology, and histology. Students will study the following organ systems: integumentary, skeletal, muscular, cardiovascular, lymphatic, and respiratory. In the accompanying laboratory, students will learn basic terminology, microscopy, animal dissection, organ dissection, and experimental process and protocols.</td>
</tr>
<tr>
<td><strong>Requisites</strong></td>
<td>Prerequisites: high school chemistry, CHE 1500 (Introduction to Chemistry), or CHE 1530 (Allied Health Chemistry); Corequisite: ENG 1510 (English Composition I); must meet minimum college level reading score: Accuplacer 80+. It is strongly recommended that students have an appropriate biology course.</td>
</tr>
<tr>
<td><strong>Credits and Seat Time</strong></td>
<td>4 credits, 15 weeks, 150 minutes/week each lecture and lab.</td>
</tr>
<tr>
<td><strong>Lecture Content Sequence</strong></td>
<td>Major Themes: Chemistry, Cells, Genetics, Histology, Organs and Organ Systems, Integumentary System, Skeletal System, Muscular System, Cardiovascular System, Lymphatic and Immune Systems, Respiratory System</td>
</tr>
<tr>
<td><strong>Lab Content Sequence</strong></td>
<td>Language of Anatomy, Organs and Organ Systems, Compound Light Microscope, Histology, Skeletal System, Muscular System, Cardiovascular System, Respiratory System</td>
</tr>
<tr>
<td><strong>Instructional Delivery</strong></td>
<td>Face-to-face lecture and lab</td>
</tr>
</tbody>
</table>

**Mindset and Self-Efficacy**

Dweck’s Implicit Theory of Intelligence Scale for adults (Dweck 2000) was used to measure mindset. The scale is a self-report survey which consists of eight assertions (Table 2). Four of the statements assess fixed mindset (assertions 1, 2, 4, and 6), and four of the statements assess growth mindset (assertions 3, 5, 7, and 8). The response to each statement was a Likert agreement scale with the following options: strongly agree, agree, mostly agree, mostly disagree, disagree, and strongly disagree. Although many authors combine the responses from all eight assertions into a single mindset score, the two sets of assertions are thought to represent related but separate constructs (Chen and Shane Tutwiler 2017, Lüftenegger and Chen 2017, Tempelaar et al. 2015). To determine which approach to use in this report, mindset data were analyzed as a single mindset score and as separate fixed and growth mindset scores. All analyses provided similar results except pre- to post-course differences in subpopulations of students were more evident when the fixed and growth mindset scores were kept separate. Therefore, responses to the fixed and growth mindset assertions are presented separately.

*continued on next page*
Table 2. Assertions used in the mindset and self-efficacy self-report surveys.

<table>
<thead>
<tr>
<th>Mindset¹</th>
<th>Self-Efficacy²</th>
</tr>
</thead>
<tbody>
<tr>
<td>You have a certain amount of intelligence, and you can’t really do much to change it.</td>
<td>I am confident I have the ability to learn the material taught in anatomy and physiology (A&amp;P).</td>
</tr>
<tr>
<td>Your intelligence is something about you that you can’t change very much.</td>
<td>I am confident I can do well in A&amp;P.</td>
</tr>
<tr>
<td>No matter who you are, you can significantly change your intelligence level.</td>
<td>I think I will do as well or better than other students in A&amp;P.</td>
</tr>
<tr>
<td>To be honest, you can’t really change how intelligent you are.</td>
<td>I don’t think I will be successful in A&amp;P.</td>
</tr>
<tr>
<td>You can always substantially change how intelligent you are.</td>
<td>I am confident that I can understand the topics taught in A&amp;P.</td>
</tr>
<tr>
<td>You can learn new things, but you can’t really change your basic intelligence.</td>
<td>I believe that if I exert enough effort, I will be successful in A&amp;P.</td>
</tr>
<tr>
<td>No matter how much intelligence you have, you can always change it quite a bit.</td>
<td>I feel like I don’t know a lot about A&amp;P compared to other students in this class.</td>
</tr>
<tr>
<td>You can change even your basic intelligence level.</td>
<td>Compared with other students in this class, I think I have good study skills.</td>
</tr>
</tbody>
</table>

¹Assertions were obtained from Dweck’s Implicit Theory of Intelligence Scale for adults (Dweck 2000, Dweck 2016).
²Assertions were obtained from Witt-Rose’s self-report anatomy and physiology course-level survey (Witt-Rose 2003).

As noted above, the fixed and growth mindset surveys each consist of four assertions. The goal is to combine responses from a set of assertions into a single score that represents the overall level of the construct in each student. Thus, some method for combining responses across assertions for each participant is required. To simplify combination and make interpretations more intuitive, response categories typically are numbered and the scale is considered interval. As a result, the agreement response category scale is ordinal, however, it cannot be assumed a consistent interval exists between adjacent responses. If that assumption is indeed not true, converting response categories to numbers could invalidate construct interpretation. Concern over this issue has been widespread (Sullivan and Artino 2013) and has been used as a basis for questioning validity of published work (Usher and Pajares 2008). However, Norman (2010) provided extensive evidence conversion of an ordinal to an interval scale does not invalidate Likert scale interpretations. Sullivan and Artino (2013) furthermore stated that number conversion techniques are the recommended approach for constructs that are measured with multiple assertions, as long as responses among different assertions are sufficiently inter-correlated. Therefore, in this study, the agreement response categories were numbered from one (strongly disagree) to six (strongly agree). Then, the scores of the responses to the four fixed mindset assertions were averaged to obtain a single score for each student. The average, instead of some other summary method, e.g., the sum or percent of total, was selected for two reasons. First, assertion scores within individual students, for each mindset construct and at each time point, were distributed normally (Shapiro-Wilk test, all p-values > 0.05). Second, the mean allows an
intuitive interpretation of the scale, e.g., an average of 4.0 on a scale of 6.0 indicates that person's central response was mostly agree. The same process was used to obtain an average individual student score for the four growth mindset assertions.

Interpretation of mindset survey scores varies among authors with some using dichotomization of an individual into either a fixed or a growth mindset based on a cutoff score whereas others interpret the scales as a continuous range of possible mindsets with a score of six on the fixed mindset scale indicating a pure fixed mindset, and a score of six on the growth mindset scale indicating a pure growth mindset. The dichotomization of mindset is not favored (MacCallum et al. 2002, Rucker et al. 2015), in this study, mindset scores were interpreted as a continuum with higher scores indicating higher levels of a fixed or growth mindset.

Reliability, i.e., inter-correlation, of the responses was evaluated with Cronbach’s alpha coefficient, which is an average internal consistency correlation (Ruel et al. 2016). Reliability was assessed separately for responses to the fixed and growth mindset assertions at each measurement time point. Only students with complete survey data as defined in Table B2 were included in reliability analyses. The validity of the fixed and growth mindset scales used in this study has been well established (Deemer 2004, Dweck 2000, Dweck 2002, Rucker et al. 2015), in this study, mindset scores were interpreted as a continuum with higher scores indicating higher levels of a fixed or growth mindset.

Self-efficacy was measured with the self-report anatomy and physiology course-level survey created by Witt-Rose (2003) (Table 2). Witt-Rose’s survey (2003) appears to be the only self-efficacy scale developed for the first HAP course. In addition to being focused at the course-level, the Witt-Rose (2003) assessment encompasses both lecture and lab and contains fifteen assertions. Eleven of the statements are written as positive beliefs (assertions 1, 2, 3, 5, 6, 8, 10, 11, 12, 13, and 15), and four of the statements are written as negative beliefs (assertions 4, 7, 9, and 14). The response to each statement was a Likert agreement scale with the following options: strongly agree, agree, mostly agree, mostly disagree, disagree, and strongly disagree. For scoring, the agreement scale was numbered from one (strongly disagree) to six (strongly agree), the four questions which were written as negative beliefs were reverse scored, and the average of the responses to all fifteen statements was calculated to obtain a single self-efficacy score for each student. Higher scores on the self-efficacy scale indicate higher levels of personal belief in one’s ability to be successful in the A & P I course. Reliability of the scale was evaluated with Cronbach’s alpha coefficient both pre- and post-course including only students with complete survey data as defined in Table B2. Because the assertions are statements about personal beliefs specific to success in a two-semester anatomy and physiology course, the set of assertions have strong face validity. Beyond face validity, the validity of the self-efficacy scale used in this study has not been established (Witt-Rose 2003), although it was used in a study which examined the association of self-efficacy with a variety of outcomes in a human anatomy course (Hargroder 2007).

Both the mindset and self-efficacy surveys were administered to students on the first (pre-course) and on the last (post-course) day of lecture class. Participation in the survey was voluntary, and informed consent was obtained at both survey time points. Surveys were administered by either Kaye Young or Kayla Griewisch and not by Ellen Lehning, the lecture instructor. In addition, Ellen Lehning did not see any individual student survey data until after final course grades were submitted. Those latter two steps were described in the informed consent document, were explained by the survey proctor, and were taken to reduce the likelihood students would think non-participation or their responses could negatively influence their grades.

Course Grades and Other Data
Final course grades were calculated for each student as course percent correct. The final course percent correct grade was a weighted average of the final lab (40%) and final lecture (60%) percent correct grades. Final course percent correct grades were converted to letter grades based on the following cutoffs: A = 90%, B+ = 87%, B = 80%, C+ = 77%, C = 70%, D+ = 67%, D = 60%, and F < 60%. Students who withdrew were categorized as W (withdrew on or after census which occurs at the time point when 20% of the course has been completed) or WB (withdraw before census).

A variety of demographic, socioeconomic, and other data were collected about each student. The additional data were provided by JCC’s Department of Institutional Research and Planning, which uses Banner Student software (http://www.elucian.com/Software/Banner-Student/) to track student information. All statistical analyses were conducted using SPSS® software according to Laerd Statistics (2015). Specific statistical methods are described in Results. This project was approved by the Institutional Review Board of JCC, and informed consent, as was noted above, was obtained from all students at both the pre- and post-course survey time points.
An Investigation of Potential Correlations between Student Self-Efficacy, Mindset, and Demographics with Final Grades in a Community College Anatomy and Physiology I Course

**Results**

*Missing Data*

Eighty-nine students were registered for the course on the first day of class. No students added the course after the first day of class. Four students who were enrolled on the first day of class were not included in analyses because: 1) one student received an incomplete, and 2) three students were withdrawn administratively for not attending any classes at all. Of the remaining eighty-five students, several had missing survey data. Missing data can alter parameter estimates, reduce statistical power, and suggest nonresponse bias all of which may invalidate statistical inferences (Montiel-Overall 2006). Therefore, to determine its potential impact, several evaluations of the missing survey data were performed and are described in Appendix B. Those analyses show that missing survey data have a minimal impact on statistical inferences in this study. Therefore, a traditional method for handling missing data, listwise deletion (Montiel-Overall 2006), was chosen. Listwise deletion eliminates all cases with any missing data leaving only students with complete data in analyses. Listwise deletion was selected so sample sizes would be balanced and to provide a consistent population of students for pre- and post-course comparisons. Thus, for letter grades of F and above, only students with complete pre- and post-survey data were included, and for the withdrawal grade categories, only students with complete pre-survey data were included.

*Demographic, Socioeconomic, and Other Characteristics of Students with Complete Data*

Demographic, socioeconomic, and other characteristics identified as associated with A & P I grades at JCC in a prior study (Russell et al. 2016) are shown in Table 3. For comparison, the characteristics of students from the prior study also are presented in Table 3. Statistical comparisons of student characteristics between the current and prior studies were not performed due to the small, one-semester sample size of the present study relative to the large thirteen-year sample size of the prior study. Non-statistical comparisons indicate there was a tendency in this study for fewer students who: 1) were white, 2) were men, 3) received a federal Pell Grant, 4) were first generation, 4) repeated any course before or with Anatomy and Physiology I, 5) took remedial math, 6) took a freshman biology or chemistry course before Anatomy and Physiology I, and 7) were older.
Table 3. Demographic, socioeconomic, and other features of the study population.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Categories</th>
<th>This Study¹</th>
<th>Prior Study²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median = 19</td>
<td>Median = 21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Range = 45</td>
<td>Range = 47</td>
</tr>
<tr>
<td>Age</td>
<td>Not applicable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>85</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td>White/unknown</td>
<td>83</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Other³</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>Received a federal Pell Grant at any time</td>
<td>No</td>
<td>50</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>50</td>
<td>63</td>
</tr>
<tr>
<td>First generation college student⁴</td>
<td>No</td>
<td>78</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>22</td>
<td>44</td>
</tr>
<tr>
<td>Repeated any course before or with A &amp; P I⁴</td>
<td>No</td>
<td>90</td>
<td>79</td>
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<td></td>
<td>Yes</td>
<td>10</td>
<td>21</td>
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<tr>
<td>Remedial reading course before A &amp; P I⁴,⁵</td>
<td>No</td>
<td>93</td>
<td>88</td>
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<tr>
<td></td>
<td>Yes</td>
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<td>Remedial math course before/with/after A &amp; P I⁴,⁵</td>
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<td></td>
<td>Yes</td>
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<td>Remedial writing course before A &amp; P I⁴,⁵</td>
<td>No</td>
<td>95</td>
<td>90</td>
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<tr>
<td></td>
<td>Yes</td>
<td>5</td>
<td>10</td>
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<td>Earned college credit before A &amp; P I⁶</td>
<td>No</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>83</td>
<td>79</td>
</tr>
<tr>
<td>Took a daytime lecture section⁶</td>
<td>Start before 4:05pm</td>
<td>72</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>Start 4:05pm or later</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>Freshman biology course before A &amp; P I⁶</td>
<td>No</td>
<td>62</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>38</td>
<td>47</td>
</tr>
<tr>
<td>Freshman chemistry course before A &amp; P I⁶</td>
<td>No</td>
<td>72</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>28</td>
<td>37</td>
</tr>
<tr>
<td>Freshman physics course before A &amp; P I⁶</td>
<td>No</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

¹Data are presented for students with complete survey data, withdrawals and non-withdrawals combined, as defined in Table B2. n = 60
²Russell et al. (2016). n = 3693
³Categories are self-reported and are the terms used in JCC’s banner database (see Methods). The other races/ethnicities were Hispanic (8%), Black (7%), and two or more ethnicities (2%).
⁴Factors identified in Russell et al. (2016) which increased the relative risk of receiving a D+ or lower grade including withdrawals in A & P I at JCC.
⁵Selected because those are the requisites for A & P I at JCC.
⁶Factors identified in Russell et al. (2016) which decreased the relative risk of receiving a D+ or lower grade including withdrawals in A & P I at JCC.
Grades of Students with Complete Survey Data
As noted above, grade performance was summarized using letter grades and course percent correct grades. Letter grade results are presented in Table 4 for students with complete survey data as defined in Table B2, including non-withdrawals and withdrawals. As stated earlier, a previous publication quantified Anatomy and Physiology I letter grade proportions at JCC (Russell et al. 2016). For comparison purposes, those data are presented in Table 5. The data in Table 5 have been modified from the original paper to not include administrative withdrawal (X) grades, as X grades were not a part of the analyses for this report. Although a statistical comparison between studies was not conducted for the reason outlined above, a non-statistical comparison shows the percentage of students who received a C and higher grade in this study was 14.1% higher than what was reported in Russell et al. (2016). Those results mainly were due to an increase in the percentage of students who received a C with a concomitant decrease in the proportion of students who received a D+, D, or F.

### Table 4. Distribution of Anatomy and Physiology I letter grades\(^1\) for students with complete survey data\(^2\).

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Individual Grade Categories</th>
<th>Combined Grades(^5)</th>
<th>Combined Grades(^6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13.3 (8)(^4)</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>5.0 (3)</td>
<td>20.0</td>
<td>73.3</td>
</tr>
<tr>
<td>B+</td>
<td>15.0 (9)</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>11.7 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C+</td>
<td>28.3 (17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>8.3 (5)</td>
<td>8.3</td>
<td>26.6</td>
</tr>
<tr>
<td>D+</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>3.3 (2)</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>15.0 (9)</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>WB(^3)</td>
<td>0.0 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100% (60)</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

\(^1\)The scale for letter grades is provided in methods.
\(^2\)Defined in Table B2.
\(^3\)W = Student withdrawal on or after census. Census occurs at the time point when 20% of the course has been completed.
\(^4\)WB = Student withdrawal before census.
\(^5\)Percent of total (sample size).
\(^6\)Percent of B and B+ categories combined, etc.
\(^\)Percent of C and above combined and D+ and lower including withdrawal categories combined.
Table 5. Distribution of Anatomy and Physiology I letter grades from Russell et al. (2016)¹.

<table>
<thead>
<tr>
<th>Letter Grade</th>
<th>Individual Grade Categories</th>
<th>Combined Grades⁴</th>
<th>Combined Grades⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13.6 (497)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B+</td>
<td>7.2 (261)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>16.4 (598)</td>
<td>23.6</td>
<td></td>
</tr>
<tr>
<td>C+</td>
<td>8.0 (290)</td>
<td></td>
<td>59.1</td>
</tr>
<tr>
<td>C</td>
<td>13.9 (505)</td>
<td>21.9</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>(164)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>8.0 (293)</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>15.5 (566)</td>
<td>15.5</td>
<td>40.9</td>
</tr>
<tr>
<td>W²</td>
<td>10.7 (389)</td>
<td></td>
<td>12.9</td>
</tr>
<tr>
<td>WB²</td>
<td>2.2 (81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100% (3644)</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

¹Because X grades were not included in this study’s analyses, the data in the table were modified from the original publication to not include X grades.
²W = Student withdrawal on or after census. Census occurs at the time point when 20% of the course has been completed.
³W = Student withdrawal before census.
⁴Percent of total (sample size).
⁵Percent of B and B+ categories combined, etc.
⁶Percent of C and above combined and D+ and lower including withdrawal categories combined.

For students with complete survey data, course percent correct grades were distributed normally (Shapiro-Wilk test, \( p = .124 \)). Thus, those data were summarized using the mean and standard deviation (77.9 ± 10.4%) and are presented with a frequency polygon in Figure 1. The data do not include students who withdrew and had complete pre-survey data because those students did not have a course percent correct grade.

Fixed Mindset, Growth Mindset, and Self-Efficacy of Students with Complete Data

All pre- and post-course fixed mindset, growth mindset, and self-efficacy Cronbach's alpha coefficients were at 0.879 or higher. Those coefficients indicate strong inter-correlation (Ruel et al. 2016). As indicated in methods, response options for fixed mindset, growth mindset, and self-efficacy were numbered from one to six with one indicating strongly disagree and six indicating strongly agree. To interpret the relative levels of each construct reported by students in this study, distributions of pre- and post-course survey scores are presented with box and whisker plots (Figure 2).

Figure 1. Frequency polygon of course percent correct data for students who did not withdraw and who had complete survey data as defined in Table B2.
An Investigation of Potential Correlations between Student Self-Efficacy, Mindset, and Demographics with Final Grades in a Community College Anatomy and Physiology I Course

How to interpret a box and whisker plot is described in Appendix B. Box and whisker plots were used due to the presence of outliers and because none of the survey variables at either time point were distributed normally (Shapiro-Wilk test, all \( p \)-values < 0.05). Distributions were skewed towards low levels of a fixed mindset, high levels of a growth mindset, and high levels of self-efficacy at both the beginning and the end of the course. Distributions of all survey variables also showed tails towards the opposite responses.

To determine if construct levels changed from the beginning to the end of the course, for each survey variable, pre-course scores were compared to post-course scores statistically. If two assumptions are met, the described comparisons should be performed with the paired-samples t-test. The two assumptions of the paired samples t-test are that post-course minus pre-course difference scores should: 1) be distributed normally and 2) not contain outliers. Difference scores for all three survey variables were distributed normally (Shapiro-Wilk test, all \( p \)-values > 0.05) but difference scores for each survey variable contained one to two outliers. Outliers were defined as values that were more than 1.5 box-lengths from the edge of the box in a box and whisker plot of the difference scores (box and whisker plots of difference scores not shown). Outliers were not due to data entry or measurement error, i.e., they were authentic student responses. Therefore, outliers were kept in analyses, and a nonparametric alternative to the paired samples t-test, the Wilcoxon signed-rank test, was performed. The Wilcoxon signed-rank test determines if the median difference score is different from zero and has one assumption: difference scores should be distributed reasonably symmetrically. As assessed by visual inspection of histograms of difference scores (Figure 3), that assumption was met. For all three survey variables, the median difference score was not statistically significantly different from zero (Table 6).

Figure 2. Box and whisker plots of survey scores for students who did not withdraw and who had complete survey data as defined in Table B2. Features of box and whisker plots are described in Appendix B. Numbers in the box are the median. Statistical procedures are described in the text.

continued on next page
Table 6. Comparison of median\(^1\) pre- and post-course fixed mindset, growth mindset, and self-efficacy scores for students who did not withdraw and had complete survey data\(^2\).

<table>
<thead>
<tr>
<th>Construct</th>
<th>Median Pre-Course</th>
<th>Median Post-Course</th>
<th>Median Difference Score(^3)</th>
<th>z-value(^1)</th>
<th>p-value(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Mindset</td>
<td>2.0</td>
<td>2.3</td>
<td>0.3</td>
<td>1.147</td>
<td>0.251</td>
</tr>
<tr>
<td>Growth Mindset</td>
<td>5.0</td>
<td>4.8</td>
<td>0.2</td>
<td>0.158</td>
<td>0.874</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>4.7</td>
<td>5.2</td>
<td>0.5</td>
<td>1.734</td>
<td>0.083</td>
</tr>
</tbody>
</table>

\(^1\)See text for a description of why data were summarized with the median and why z- and p-values were obtained using the Wilcoxon signed-rank test.

\(^2\)Defined in Table B2.

\(^3\)Post-course minus pre-course.

Although the median level of each construct was the same at the beginning and end of the course, subpopulations of students might have changed their response to a large degree, e.g., some students might have started with high levels but ended with low levels of self-efficacy. To determine if that occurred, difference scores for individual students were plotted in histograms (Figure 3). Fixed mindset scores: 1) did not change or changed by less than one level in 78.5% (40 out of 51), 2) increased by one to three levels in 17.6% (9 out of 51), and 3) decreased by one to one and a half levels in 3.9% (2 out of 51) of students. Growth mindset scores: 1) did not change or changed by less than one level in 84.3% (43 out of 51), 2) increased by one to three levels in 11.8% (6 out of 51), and 3) decreased by one to one and a half levels in 3.9% (2 out of 51) of students. Self-efficacy scores: 1) did not change or changed by less than one level in 71.6% (36 out of 51), 2) increased by one to two and a half levels in 19.6% (10 out of 51), and 3) decreased by one to three levels in 9.8% (5 out of 51) of students.

Figure 3. Frequency histograms of post-course minus pre-course difference scores for students who did not withdraw and who had complete survey data as defined in Table B2. The numbers on the bars are the count of students within each bar. Statistical procedures are described in the text.
Factors Associated with Course Percent Grades for Students with Complete Data
It was hoped survey scores of students who withdrew could be compared statistically to survey scores of students who did not withdraw. However, because survey scores of students who did not withdraw were not distributed normally, and because the small sample size ($n = 9$) of students who did withdraw resulted in an imprecise estimate of their median (see ahead), statistical comparisons were not performed. Instead, the survey scores for students who withdrew are presented as box and whisker plots in Figure 4. In the fixed and growth mindset plots, the median and 75th percentile have the same value. The median and 75th percentile are the same because of a small sample size, a tight range, and the calculation method (Tukey’s hinge) used by SPSS® in box plots. Withdrawals reported low levels of a fixed mindset, high levels of a growth mindset, and moderately high levels of self-efficacy. Non-statistical comparisons suggest median self-efficacy scores may have been lower in withdrawals (Figure 4) than non-withdrawals post-course (Figure 2) whereas fixed and growth mindset median scores did not appear to be different between withdrawals and non-withdrawals pre- or post-course.

Including only students with complete data who did not withdraw, analyses of factors associated with course grades were conducted using multiple linear regression. Course percent correct grades were the dependent variable. Course percent correct grades are continuous data, and thus, allow a precise titration of the change in grade associated with a specified change in an independent variable. Initially, all factors listed in Table 3 except “took a freshman physics course before A & P I” were included as independent variables. Taking a freshman physics course in advance of A & P I was not included since the sample size was one. Initially, pre- and post-course fixed mindset, growth mindset, and self-efficacy survey variables also were included as independent variables. Multiple linear regression models were developed using Enter (all variables added at the beginning), hierarchical (all independent variables except survey variables entered first and survey scores entered second), and stepwise forward regression ($\alpha$ levels of 0.05 and 0.10 were chosen for entry and removal of independent variables). All three model results were very consistent providing nearly identical adjusted $R^2$ values and coefficient estimates as well as identifying the same independent variables as statistically significantly associated with grades. Data are presented for the Enter model. Prior to providing Enter model results, model assumptions are described. Multiple linear regression analyses should meet the following assumptions to provide valid models:

- The dependent variable must be continuous. As explained above, course percent correct grades are continuous.
- The model must include two or more independent variables, which can be either continuous (i.e., an interval or ratio variable) or categorical (i.e., an ordinal or nominal variable). All independent variables were continuous or categorical (Table 3).
- Observations, i.e., residuals, should be independent of each other. Pre- and post-course survey data were related since the same students were measured at each time point. Thus, only post-course and not pre-course survey data were included in the regression model. Scatter plots show the pre-course variables do not have a relationship to course percent correct grades (Figure 5) suggesting no information was lost by not including pre-course survey data in the regression model. The Durbin-Watson statistic was used to test the independence of observations for the rest of the independent variables. A value of 2.0 indicates independence of observations. The Durbin-Watson statistic was 1.955.
A linear relationship should exist between the dependent variable and the independent variables collectively. If a scatterplot of studentized residuals versus unstandardized predicted values are in a horizontal band, this assumption is likely to be met. The plot did show a horizontal band (plot not shown).

A linear relationship should exist between the dependent variable and each of the continuous independent variables. If partial regression plots of the dependent variable against each continuous independent variable show either a linear relationship or horizontal band, i.e., they do not show a nonlinear association, this assumption is likely to be met. All plots showed either a horizontal band or a linear relationship (plots not shown).

The data should show homoscedasticity of residuals (equal error variances). If in a scatterplot of studentized residuals versus unstandardized predicted values, the spread of the residuals does not increase or decrease across the predicted values, this assumption is likely to be met. The plot showed an even distribution of residuals across predicted values (plot not shown).

The data should not show multicollinearity. Multicollinearity occurs when two or more independent variables are highly correlated with each other. Multicollinearity is detected with Pearson correlations. Pearson correlations should not exceed 0.7. For all survey variables, pre- and post-course survey data were correlated with correlation values greater than 0.7. This is another reason why pre-course survey data were not included in the regression model. Age also showed Pearson correlations greater than 0.7 with time-related independent variables, e.g., prior college credit. In the previous study (Russell et al. 2016) at JCC, a similar problem with age occurred. In that study, the multiplicative inverse, i.e., the reciprocal, of age was used instead of age and that eliminated the issue allowing inclusion of age in the model. Therefore, the reciprocal of age was calculated. Once pre-course survey data were eliminated and the reciprocal of age was used, all correlations were less than 0.7 with a predominance of correlations less than 0.3 (data not shown). Multicollinearity also is examined by calculating tolerance and the variance inflation factor (VIF). Tolerance should be greater than 0.1, and VIF should be less than 10 but Allison (2012) suggests VIF should be less than 2.5. For all survey variables, pre- and post-course survey data and age exceeded the suggested limits. Once pre-course survey data were eliminated from the model and the reciprocal of age was used, all tolerance and VIF limits were met (data not shown).

**Figure 5.** Scatter plots of individual students’ survey scores versus course percent correct grades for students who did not withdraw and who had complete survey data as defined in Table B2. A = Pre-Course. B = Post-Course.
The data should not include significant outliers, highly influential points, or high leverage points. For outliers, standardized residuals and studentized deleted residuals should not exceed ± 3 standard deviations. All standardized and studentized residuals were within ± 3 standard deviations (data not shown). For influential points, Cooks’ distance should not be greater than one. All Cooks’ distances were less than one (data not shown). For leverage points, values: 1) less than 0.2 are safe, 2) equal to or greater than 0.2 and less than 0.5 are risky, and 3) greater than or equal to 0.5 are dangerous (Huber 1981). Thirty-five leverage points were risky, and six leverage points were dangerous with values between 0.5 and 0.7 (data not shown). The model was re-run without the dangerous leverage points. Removing the dangerous leverage points did not change the overall fit of the model or which variables were considered statistically significant and only very slightly changed estimates of coefficients. Therefore, those leverage points were left in the dataset.

Residuals (errors) should be approximately normally distributed. Normality was assessed by visual examination of Q-Q plots of studentized residuals, which should follow a nearly diagonal line. Inspection of the Q-Q plots showed near normal distribution of the residuals (plots not shown).

Since all assumptions of the multiple linear regression were met, the overall fit of the model was examined next. $R^2$ for the overall model was 66.9% with an adjusted $R^2$ of 51.3%, a large sized coefficient of determination according to Cohen et al. (2003). Overall, the independent variables included in the model statistically significantly predicted course percent correct grades ($F(16,34) = 4.294, p < .0005$). Bivariate correlations, partial correlations, and $p$-values for all independent variables are provided in Table 7. Of the independent variables examined, two were statistically significantly associated with course percent correct grades: post-course self-efficacy and gender.

### Table 7. Correlations and statistical significance of independent variables examined for inclusion in the multiple regression model.

<table>
<thead>
<tr>
<th>Independent Variable 2</th>
<th>Bivariate $r^4$</th>
<th>Partial $r^5$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-course self-efficacy</td>
<td>0.661</td>
<td>0.629</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Gender</td>
<td>0.312</td>
<td>0.338</td>
<td>0.044</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td>-0.245</td>
<td>-0.322</td>
<td>0.055</td>
</tr>
<tr>
<td>Remedial reading course before A &amp; P I</td>
<td>-0.040</td>
<td>0.237</td>
<td>0.164</td>
</tr>
<tr>
<td>Remedial writing course before A &amp; P I</td>
<td>-0.031</td>
<td>-0.236</td>
<td>0.166</td>
</tr>
<tr>
<td>Multiplicative inverse of age 3</td>
<td>-0.286</td>
<td>-0.193</td>
<td>0.261</td>
</tr>
<tr>
<td>Remedial math course before/with/after A &amp; P I</td>
<td>-0.083</td>
<td>-0.187</td>
<td>0.275</td>
</tr>
<tr>
<td>Repeated any course before or with A &amp; P I</td>
<td>-0.017</td>
<td>0.094</td>
<td>0.549</td>
</tr>
<tr>
<td>Freshman biology course before A &amp; P I</td>
<td>0.236</td>
<td>0.097</td>
<td>0.572</td>
</tr>
<tr>
<td>Post-course growth mindset</td>
<td>-0.058</td>
<td>-0.091</td>
<td>0.597</td>
</tr>
<tr>
<td>Freshman chemistry course before A &amp; P I</td>
<td>0.047</td>
<td>-0.085</td>
<td>0.624</td>
</tr>
<tr>
<td>Took a daytime lecture section</td>
<td>0.198</td>
<td>0.045</td>
<td>0.794</td>
</tr>
<tr>
<td>First generation college student</td>
<td>-0.139</td>
<td>-0.042</td>
<td>0.806</td>
</tr>
<tr>
<td>Post-course fixed mindset</td>
<td>-0.166</td>
<td>-0.030</td>
<td>0.863</td>
</tr>
<tr>
<td>Received a federal Pell Grant at any time</td>
<td>0.019</td>
<td>-0.010</td>
<td>0.952</td>
</tr>
<tr>
<td>Earned college credit before A &amp; P I</td>
<td>0.162</td>
<td>0.006</td>
<td>0.971</td>
</tr>
</tbody>
</table>

$^1$See Results for a description of the overall fit of the multiple linear regression model.

$^2$See Table 3 for a description of the independent variables.

$^3$See Results for a description of why the reciprocal of age was used.

$^4$Represents the correlation between each independent variable and final course percent correct grades.

$^5$Represents the partial correlation between each independent variable and final course percent correct grades controlling for all other independent variables.

continued on next page
In addition to identifying statistically significantly associated factors, an additional goal of multiple regression analyses is to quantify the strength of the association of an independent variable with the dependent variable. For multiple linear regression, the strength of the association is measured with an unstandardized $\beta$ coefficient with a 95% confidence interval. Unstandardized $\beta$ coefficients, confidence intervals, t-values and $p$-values are presented in Table 8. The strength of each association is summarized below:

- An increase of one in the post-course self-efficacy score was associated with an increase of 7.4% in the course percent correct grade.
- Females had course percent correct grades that were on average 7.2% higher than males, all other things being equal.

**Table 8. Unstandardized $\beta$ coefficients with 95% confidence intervals (C.I.) for independent variables statistically significantly associated with course percent correct grades.**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Unstandardized $\beta$ Coefficient</th>
<th>95% C.I.</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-course self-efficacy</td>
<td>7.415</td>
<td>4.218 - 10.613</td>
<td>4.713</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Gender</td>
<td>7.215</td>
<td>0.208 - 14.223</td>
<td>2.092</td>
<td>0.044</td>
</tr>
</tbody>
</table>

$^1$See Results for a description of the overall fit of the multiple linear regression model and Table 7 for statistical significance of all independent variables.

**Discussion**

**Course Grades**

Students performed well with a class percent correct of 77.9 ± 10.4% (mean ± standard deviation) which translated into a large proportion (73.3%) of students receiving C and higher letter grades. Those letter grade results are better than the established baseline at JCC (59.1% at C and above) and are above the international average (rough estimate of two-thirds receive grades defined as unsuccessful or failing; see Russell et al. (2016). It is not clear why students in this study did well. The study population contained fewer at risk students than in the previous study at JCC (Russell et al. 2016) which might explain the higher grades. Also, during the semester when this study was performed, several lecture and lab instructors instituted a variety of learning interventions in conjunction with an official SUNY course assessment. Perhaps those interventions and having a lower proportion of at-risk students played a role in the solid grade performance of the students in this study.

**Levels of Mindset and Self-Efficacy**

Most students asserted lower levels of a fixed mindset and higher levels of a growth mindset at the beginning and end of the course. The mindset assertions are written in the second person (Dweck 2000), i.e., the assertions state “you” instead of “I” (Table 2). Because of that approach, it is not possible to conclude students believed they personally had a growth mindset but rather students believed people in general can change and improve their intelligence. Although median levels of growth and fixed mindset were the same at the beginning and end of the course, a small subpopulation of students (17.6%) did report moderate to large increases in levels of fixed mindset at the end of the course. Thus, some students lessened their belief people can improve their intelligence. It is of concern if the change from more of a growth to more of a fixed mindset was caused by a student’s experiences in the course. Whether or not mindset levels are associated with grades or other measures or academic achievement in the short-term, learning experiences should not lead to negative belief systems which might have long-term consequences. To sort this out, further work on how taking the first HAP course is impacting mindset is required.

Most students reported high levels of self-efficacy at both the beginning and end of the course. The self-efficacy assertions were written in the first person (Witt-Rose 2003), i.e., the assertions state “I” instead of “you” (Table 2). Because
of that approach, it is possible to conclude most students believed they personally had the requisite set of abilities to be successful in the Anatomy and Physiology I course. Although median levels of self-efficacy did not change from the beginning to end of the course, two subpopulations of students were evident. One subpopulation (19.6%) showed a moderate increase in self-efficacy whereas the other subpopulation (9.8%) showed a marked decrease in self-efficacy at the end of the course. Because self-efficacy assertions were written in the first person, were specific to the Anatomy and Physiology I course, and changed in a noteworthy proportion (29.4%) of students, it is possible these effects were related to students’ experiences in the course. Thus, for some students, participation in the course might be quelling whereas for others it could be enhancing their Anatomy and Physiology I efficacy beliefs. These findings also suggest self-efficacy is malleable. If so, purposeful self-efficacy interventions may not only improve but actually may be required to prevent the loss of a student’s belief in their ability to succeed in Anatomy and Physiology I.

**Association of Mindset, Self-Efficacy and Other Factors with Course Grades**

Based on visual inspection of scatterplots (Figure 5), neither fixed nor growth pre-course mindset were associated with course percent correct grades. Based on multiple linear regression analyses (Table 7), neither fixed nor growth post-course mindset were associated with course percent correct grades. These findings are counter to research which has suggested mindset is not only predictive but an important, malleable causative factor in academic achievement (Blackwell et al. 2007, Dweck 2000, Dweck 2016, Fillmore 2015, Sriram et al. 2007, Dweck 2016, Sriram et al. 2007). These findings, though, are consistent with another body of work which has not uncovered a relationship between mindset and academic performance (Bazelaia et al. 2018, Clevenger 2013, Kajjanaho and Tirronen 2018, Macnamara and Rupani 2017, Zonnefeld 2015). The results of this study also are harmonious with the results of Cavanagh et al. (2018) who did not detect any relationship between mindset and final course percent correct grades in the first HAP course. Thus, at this point for the first HAP course, two studies have not been able to discern an association between mindset and course percent correct grades. Because mindset may mediate other important non-cognitive factors (Cavanagh et al. 2018), more work on mindset in the context of the first HAP course needs to be performed.

Based on visual inspection of scatterplots (Figure 5), pre-course self-efficacy was not associated with course percent correct grades. Based on multiple linear regression analyses (Table 7), an increase of one level of post-course self-efficacy related to a 7.4% increase in the final course percent correct grade. This finding is consistent with that of Witt-Rose (2003) who also found a highly significant relationship between self-efficacy and mid-term and final course grades in the first HAP course. Thus, at this point for the first HAP course, two studies have been able to find strong associations between self-efficacy and course grades. These findings are consistent with a large, broad array of research which has consistently associated self-efficacy to academic achievement (Bartimo-Aufflick et al. 2015, Honicke and Broadbent 2016, Tembo and Ngwira 2016). Importantly, self-efficacy has been found to: 1) be malleable (Gess 2015, Wernersback et al. 2014, Tembo and Ngwira 2016), 2) iteratively improve performance, i.e., as learning improves, self-efficacy improves, which in turn increases learning (Talsma et al. 2018), and 3) be a chief mediator of other non-cognitive factors including self-discipline, achievement motivation, and self-regulated learning (Jung et al 2017, Yusuf 2011). Thus, self-efficacy is an intervention target which could markedly enhance grade performance in the first HAP course. Devising self-efficacy interventions is feasible as self-efficacy is produced via four types of experiences: 1) mastery experiences (genuine performances), 2) vicarious experiences (observing others), 3) verbal and other forms of persuasion, and 4) physiological and affective states produced by experiences (Artino 2012). Mastery experiences are the most important suggesting authentic performances in an active learning environment with feedback is crucial to developing positive self-efficacy beliefs. Artino (2012) suggests the following specific intervention targets for self-efficacy:

- “Help students set clear and specific goals.” (p. 81)
- “Encourage the use of challenging and proximal goals.” (p. 81-82)
- “Provide honest, explicit feedback to increase students’ efficacy beliefs.” (p. 82)
- “Facilitate accurate calibration of self-efficacy.” (p. 82)
- “Use peer modeling to build self-efficacy.” (p. 83)

In addition to post-course self-efficacy, gender was associated with course percent correct grades with females performing 7.2% better than males. In the prior study at JCC (Russell et al. 2016), that factor was not associated with course letter grades. Other studies also have not found a relationship between gender and grades in the first HAP course (Harris et al. 2004, Witt-Rose 2003). Because of the few studies in which gender has been examined in the context of the first HAP course, and because student demographics often are not reported (Russell et al. 2016), it is difficult to interpret the inconsistency of the gender findings. In the present study, there was a larger percentage of women than in the previous study at JCC. The increased size of that population might have allowed detection of the gender association. Gender could represent college readiness differences that produce an achievement gap. To determine if gender does play a role and why, more research will need to be conducted with that attribute in the context of the first HAP course.

In this study, age; first generation; repeating any course before or with Anatomy and Physiology I; took a remedial reading, writing, or math course; earned college credit before Anatomy
and Physiology I; took a daytime lecture section; and took a
freshman biology or chemistry course before Anatomy and
Physiology I were not associated with course percent correct
grades. In the previous study at JCC (Russell et al. 2016), those
factors were associated with course letter grades. It is possible
associations were not detected in this study because: 1) student
demographics were different (Table 3), 2) students in this
study achieved higher grades than in the previous study,
i.e., there were fewer at risk students, 3) the sample size of this
study was small, and 4) students who withdrew could not be
included in the multiple regression analyses. The different
findings of the two studies show the importance of reporting
and assessing demographic factors, establishing baseline
results, continually monitoring results as sources of variation
change, and unpacking associations so that causal rather than
correlational relationships can be established.

Study Limitations
Even though a set of detailed analyses concluded missing
survey data had a minimal impact on the results of this
study, it is possible one or more unidentified factors were
confounded with the independent and/or dependent
variables. Also, the sample size of the study population was
relatively small. Together, those limitations indicate the
findings of this study require replication.

Data were measured from students in an authentic but
uncontrolled context. In such a setting, factors identified as
statistically significantly associated with course percent correct
grades are correlative and cannot be interpreted as causative.
Furthermore, data were obtained from a student population
with specific demographic characteristics. These findings
should only be applied to student populations with similar
demographic features.

Student self-report surveys were used to measure mindset
and self-efficacy. Such measures are susceptible to numerous
forms of bias because students: 1) may not understand the
content of survey questions, 2) can have different frames of
reference, 3) often select answers they perceive are desired,
and 4) might fake answers because they are embarrassed by
a truthful response. In addition, the self-efficacy survey used
in this study has not been validated, although this is the now
the third report which has used the survey in the context of
human anatomy and/or physiology (Hargroder 2007, Witt-Rose
2003). Teacher reports and performance tasks can be used to
supplement or in place of student self-reports and enhance
the validity of construct interpretation (Duckworth and Yeager
2015). Thus, to ensure findings are meaningful, future work on
the association of non-cognitive factors and success in the first
HAP course should consider in addition to self-report surveys
the use of teacher reports and performance tasks.

Summary and Future Directions
This study examined the association of mindset, self-efficacy,
demographic, socioeconomic, and other factors with course
percent correct grades in the first HAP course. The results of
this study replicate previous findings on those relationships
in the first HAP course: mindset is not but self-efficacy is
associated with course grades. Because mindset may mediate
other important non-cognitive factors (Cavanagh et al. 2018),
much work on mindset in the context of the first HAP course
needs to be performed. Because self-efficacy is malleable and
is strongly related to course grades in the first HAP course,
self-efficacy interventions targeted at specific cognitive and
non-cognitive factors which enhance learning should be designed
and evaluated. Gender also was associated with course
percent correct grades with females outperforming males.
Two other studies have not found such a relationship. The
reason for the discrepancy is unclear and requires more work.
If gender does play a role, uncovering the reason behind the
gender achievement gap could help reduce course attrition in
the first HAP course.

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The authors are employees of Jamestown Community College,
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enhance their educational practices. Kayla Griewisch uses data
analytics to help instructors improve learning and increase
retention. Andrew Pitoniak and Ellen J. Lehning are human
anatomy and physiology faculty.

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Grif. As explained in the Introduction, assessing grif was one of the goals of this publication. However, after grif data were collected, multiple recent publications cast serious reservations on the validity of grif’s construct (Credè 2018, Credè et al., 2017, Schmidt et al. 2018, Vazsonyi et al. 2018). Therefore, grif data, although collected, were not analyzed formally and are not presented or discussed in the main body of this paper. However, for documentation purposes, grif data are presented in this appendix. Grif scores were obtained from the short grif scale survey which consists of eight assertions (Duckworth and Quinn 2009). Four of the statements are written as positive beliefs and four of the statements are written as negative beliefs. The response to each statement was a Likert agreement scale with the following options: very much like me, mostly like me, somewhat like me, not much like me, and not like me at all. For scoring, the agreement scale was numbered from one (not much like me) to five (very much like me), the four questions which were written as negative beliefs were reverse scored, and the average of the responses to all eight statements was calculated to obtain a single grif score for each student. Students reported high levels of grif both pre- and post-course (Figure A1). Visual examination of scatterplots suggests grif scores were not related to course percent correct grades (Figure A1).

Figure A1. The top graph shows box and whisker plots of grif survey scores pre- and post-course. Features of box and whisker plots are described in Appendix B. The bottom two graphs are scatter plots of individual students’ grif pre- and post-course survey scores versus course percent correct grades. A = Pre-Course. B = Post-Course. All data are for students who did not withdraw and who had complete survey data as defined in Table B2.
Missing Data Analyses. The types and frequency of missing survey data were identified and then, subgrouped into non-withdrawals and withdrawals (Table B1). Non-withdrawals refer to students who were enrolled in the course through the last day of class. Withdrawals refer to students who withdrew from the course before the last day of class. Subgrouping was used because: 1) students who withdrew were available to do the pre-course survey but were not available to do the post-course survey, and 2) it allowed comparisons of withdrawals to non-withdrawals.

Table B1. Types and frequency of missing survey data.

<table>
<thead>
<tr>
<th>Type of Missing Survey Data</th>
<th>n for Nonwithdrawals</th>
<th>n for Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>One or more survey assertion non-responses</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>All pre-course survey data for fixed mindset, growth mindset, and self-efficacy</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>All post-course survey data for fixed mindset, growth mindset, and self-efficacy</td>
<td>9</td>
<td>Not applicable4</td>
</tr>
<tr>
<td>All pre- and post-course survey data for fixed mindset, growth mindset, and self-efficacy</td>
<td>2</td>
<td>Not applicable4</td>
</tr>
<tr>
<td>None5</td>
<td>51</td>
<td>9</td>
</tr>
</tbody>
</table>

1Students who were enrolled in the course through the last day of class.
2Students who withdrew from the course before the last day of class.
3At either or both of the survey time points and for any or all of the fixed mindset, growth mindset, and/or self-efficacy surveys, students did not respond to one or more of the individual survey assertions.
4Not applicable because students who withdrew from the course were not available to do the post-course survey.
5Students who were not missing any survey data at all, i.e., students with complete survey data.

Missing survey data identified in Table B1 were used to calculate survey response rates. Response rates were combined into two categories: students with complete survey data and students missing any survey data. The latter is a combination of all of the missing survey data categories listed in Table B1. Missing survey data categories were collapsed into a single missing any survey data category to allow use of: 1) Fisher’s exact test (see ahead), and 2) listwise deletion (see Methods). Survey response rates are presented in Table B2. Cutoffs which stipulate sufficient survey response returns have not been specified; however, it is generally agreed the higher the response rate, the more likely the sample is representative of the population under consideration (Montiel-Overall 2006). Response rates were relatively high at 69.9% and 75.0% for non-withdrawals and withdrawals, respectively.

Table B2. Survey response rates.

<table>
<thead>
<tr>
<th></th>
<th>n for Nonwithdrawals</th>
<th>n for Withdrawals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete survey data1</td>
<td>51</td>
<td>9</td>
</tr>
<tr>
<td>Missing any survey data2</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Total n</td>
<td>73</td>
<td>12</td>
</tr>
<tr>
<td>Response rate</td>
<td>69.9%</td>
<td>75.0%</td>
</tr>
</tbody>
</table>

1Defined in Table B1.
2Includes all missing survey data categories defined in Table B1 combined.
Even given good response rates, one or more characteristics of the missing survey data could be confounded with independent variables. If missing data are confounded to a sufficient degree, statistical inferences are invalid (Standish and Umbach 2018). However, if missing data are missing completely at random, it can be assumed missing data are not confounded (Montiel-Overall 2006). In this study, fixed mindset, growth mindset, and self-efficacy survey variables were independent variables and contained missing data. Little's test (Little and Rubin 2002) is the recommended test for examining the randomness of missing data (Montiel-Overall 2006). That test compares the distributions of missing vs. complete data across variables with missing data. Acceptance of the null hypothesis indicates data are missing completely at random. Little's test was conducted across the six independent survey variables (pre- and post-course fixed mindset, pre- and post-course growth mindset, and pre- and post-course self-efficacy), and the null hypothesis was accepted ($p = 0.482$). That result supports the conclusion survey data were missing completely at random.

One or more characteristics of missing survey data also might be confounded with dependent variables (Standish and Umbach 2018). In this study, course grades are the dependent variables. Since all students had course grades regardless of whether or not they had missing survey data, course grades were compared between students with complete survey data and students missing any survey data as defined in Table B2. That comparison was conducted for both letter grades and for course percent correct grades. Letter grades were examined using Fisher’s Exact test because it is considered the most accurate test for comparing ordinal data with small sample sizes as was the situation for the letter grade data in this study. The tradeoff is that both the independent and dependent variables can have no more than two categories, i.e., data must fit into a 2x2 contingency table. That is one reason why all of the missing survey data categories were collapsed into a single category as described above. Letter grades therefore also were combined into two categories: the frequency of students who received a C or higher letter grade and the frequency of students who received a D+ or lower letter grade including withdrawals. Those groupings were selected because a C or higher grade is required in the first HAP course to progress in most healthcare vocational programs. The 2x2 contingency table for letter grades is shown in Table B3. Letter grades were not statistically significantly different between students with complete survey data and students missing any survey data ($p = 0.438$, 2-sided).

Table B3. 2x2 Contingency table of observed values for Fisher’s Exact test comparing letter grades between students, withdrawals and non-withdrawals combined, with complete survey data and students missing any survey data.

<table>
<thead>
<tr>
<th></th>
<th>Complete Survey Data¹</th>
<th>Missing Any Survey Data²</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>C or higher³</td>
<td>44 (73.3)</td>
<td>16 (64.0)</td>
<td>60</td>
</tr>
<tr>
<td>D+ or lower⁴</td>
<td>16 (26.7)</td>
<td>9 (36.0)</td>
<td>25</td>
</tr>
<tr>
<td>Column Total</td>
<td>60</td>
<td>25</td>
<td>85</td>
</tr>
</tbody>
</table>

¹Defined in Table B2.
²Defined in Table B2.
³Includes A, B+, B, C+, and C letter grades. The scale for letter grades is provided in methods.
⁴Includes D+, D, F, W (Withdrawal on or after census. Census occurs at the time point when 20% of the course has been completed.), and WB (Withdrawal before census) letter grades.
⁵Sample size (percent of column total). The proportion of students receiving a C or higher grade was not statistically significantly different between the complete and missing any survey data groups ($p = 0.438$, 2-sided)

In addition to letter grades, course percent correct grades of students with complete survey data were compared to course percent correct grades of students missing any survey data. If assumptions are met, the described comparison should be performed with the Independent-samples t-test. However, three assumptions were not met: 1) course percent correct data for students missing any survey data were not distributed normally (Shapiro-Wilk test, $p < 0.001$), 2) variances of the two grade groups were not equal (Levene’s test for equality of variances, $p = 0.013$), and 3) both grade groups contained outliers (Figure B1). As the suspected outliers were low grades typical in the course, it was decided to keep those data in analyses. The inability to meet assumptions of the Independent Samples t-test limited the comparison to the Independent Samples Mann-Whitney U test.
The Mann Whitney U test follows a two-stage analysis. First, distributions of the two groups are compared. If the distributions have the same shape, one can proceed and compare medians. If the distributions of the two groups do not have the same shape, medians cannot be compared and the statistical finding is limited to saying the shape of the distributions are not the same. Whether or not the distributions of the two groups have a similar shape is a judgment made from visual observation of plots of the distributions. Thus, distributions of course percent correct grades for students with complete or missing any survey data were depicted with box and whisker plots as shown in Figure B1. In the box and whisker plots, the lower line represents the minimum, the bottom of the box represents the 1st quartile (the 25th percentile), the solid line in the box represents the median, the top of the box represents the 3rd quartile (the 75th percentile), and the top line represents the maximum. If there is an individual symbol above or below a box and whisker plot, that value is greater than 1.5 x the range between the first and third quartile (IQR) and identifies outliers. For those cases, the lower lines in the plot then represent 1.5 x the IQR. Distributions of the course percent correct grades were judged similar for both grade groups, as assessed by visual inspection of the box and whisker plots. Thus, the assumptions of the Mann Whitney U test were met, and medians then were compared. The median course percent correct grade was not statistically significantly different between students with complete survey data and students missing any survey data ($U = 637, z = 0.914, p = 0.361$). High survey response rates, results of Little's test, and grade comparisons all support the conclusion missing survey data will have a minimal impact on statistical inferences in this study.

![Figure B1](image-url)
Comparison of Traditional and Gamified Student Response Systems in an Undergraduate Human Anatomy Course

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Abstract

Student response systems (SRSs) are widely used in anatomy and physiology courses as a form of active learning. While traditional SRSs (clickers) are pervasive, gamified SRSs such as Kahoot! are becoming increasingly popular. However, the impact of using both types of systems in the same course is unknown. The goal of this study was to determine the relative impact of a traditional SRS (iClickers) and a gamified SRS (Kahoot!) in an undergraduate human anatomy course. Student performance on iClicker questions and Kahoot! questions were compared to their average examination performance to determine if there were potential correlations. There were nearly identical and significant positive correlations between iClicker performance and exam performance and Kahoot! performance and exam performance. Students also perceived iClickers and Kahoot! as equally fun and effective, but reported that iClickers should be used more frequently than Kahoot!. These results suggest that iClickers and Kahoot! have positive educational impacts when used together. https://doi.org/10.21692/haps.2019.001

Key words: human anatomy, clickers, personal response systems, gamified learning, Kahoot!

Introduction

Active learning has been shown to be an effective form of pedagogy for science, technology, engineering, and math (STEM) courses (Freeman et al. 2014), including anatomy and physiology (Rao and DiCarlo 2001; Michael 2006; Shaffer 2016). Active learning can take many forms, including small group work, problem solving, brief writing assignments, and peer instruction (Allen and Tanner 2005), and the use of student response systems has recently been increasing. Student response systems (SRSs) are typically wireless devices that students use to answer questions in a classroom, allowing instructors to gauge student learning and understanding in real time (Blasco-Arcas et al. 2013). While the styles of SRSs have changed over the years (Barber and Njus 2007), as of this writing there are several popular formats including physical devices that students purchase and bring to class, systems that allow for text-based answers, and systems that make use of students' own personal devices (smartphones, tablets, or laptops) to answer questions. Questions posed by SRSs are often limited to multiple choice, but depending on the system being used, they can also include numeric entry, short answer, essay, “heat map” or identification, drawing, graphing, sorting, ranking, and uploading images.

While there are many current options for SRSs and question types, the majority of prior research on SRSs has focused on traditional SRSs where students bring a physical device to class and answer multiple-choice questions (from now on referred to as using “clickers”). The use of clickers is very common in biology (Allen and Tanner 2005; Caldwell 2007; Smith et al. 2009; Smith et al. 2011). There have been many reports on the use of clickers in anatomy and physiology courses as well. In a comparison of three teaching methods, Carpenter and Boh (2008) found that undergraduate anatomy and physiology students performed best on quizzes when taught with clickers and also that students preferred using clickers in the classroom compared to other methods. When used for pre-test reviews in an undergraduate nursing anatomy and physiology course, students reported positive attitudes and perceived benefits despite no actual gains in examination performance (Stein et al. 2006). In a medical school gross anatomy course, the use of a traditional SRS system improved examination performance for the lowest quartile of students but had limited benefits for the other students in the course (Hoyt et al. 2010). Alexander et al. (2009) found a strong significant correlation between performance on clicker questions and exam performance in medical school anatomy and histology courses. Both physical therapy students and instructors had positive views of a clicker system in a human gross anatomy class (Wait et al. 2009). Overall, these studies and others highlight the positive impacts of using traditional clickers in anatomy and physiology courses. Benefits of using clickers have also been reported in a variety of other non-biology science disciplines (Wieman and Perkins 2005; Stowell and Nelson 2007; MacArthur and Jones 2008; Morling et al. 2008; Bunce et al. 2010; Schmidt 2011; Donohue 2014).
Comparison of Traditional and Gamified Student Response Systems in an Undergraduate Human Anatomy Course

Gamification is a recent development in higher education in which game-like elements are used to promote learning and engagement in the classroom (Kapp et al. 2014). Gamification has been incorporated into SRSs as well by accompanying questions with music, animations, leaderboards, and trophies or badges, all designed to give the educational experience a more game-like environment. One of the most popular gamified SRSs is Kahoot!, which has reported to have over 50 million unique monthly active users as of May 2017 (Chowdhry 2017). Kahoot! is a free web-based SRS where students answer questions anonymously with their own smartphone, tablet, or laptop and earn points based on correctness and speed. While research on gamification of SRSs is still in the early stages, there have been some studies showing possible benefits of these systems. Students in a medical microbiology course had very positive views towards a gamified clicker system and reported that they enjoyed the competition with their peers and the high degree of focus on the game (Pettit et al. 2015). Kahoot! was used in an undergraduate psychology class and students who engaged with Kahoot! earned significantly higher exam scores than students who did not (Iwamoto et al. 2017). Additionally, positive student attitudes have been reported towards using Kahoot! (Bicen and Kocakoyun 2017; Ismail and Mohammad 2017; Plump and LaRosa 2017; Licorish et al. 2018). However, one study demonstrated a “wear out” effect of using Kahoot! wherein the more often it was used in a course the less excited students were when they played it (Wang 2015).

While there are clear benefits of both traditional and gamified SRSs, to our knowledge there has been no direct comparison of the use of both in a single course. In this study, we sought to determine the impact of using both a traditional SRS (iClickers) and a gamified SRS (Kahoot!) in an undergraduate human anatomy course. Specifically, we were testing the hypothesis that performance on iClicker questions would more strongly correlate with exam performance than the correlation between Kahoot! question performance and exam performance and that students would prefer using Kahoot! more in class because it would be perceived as more fun than iClickers. Our results demonstrate that student performance on exams was equally correlated with iClicker and Kahoot! performance and that students equally preferred the use of iClickers and Kahoot! in class.

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

The study surveyed 255 students in two sections of this course: Winter 2016 (n = 127) and Spring 2016 (n = 128). Students enrolled in this course majored in biological sciences (65.6%), nursing sciences (16.0%), pharmaceutical sciences (10.9%), or other (7.4%). The majority of the population was female (70.3%) and Asian (71.5%). The remaining ethnic breakdown was 13.3% Caucasian, 12.9% Latino/a, and 1.6% African-American. A passing grade of “C” or better in a human physiology lecture course was a pre-requisite for enrolling in this human anatomy course. The course was an elective for all majors (except nursing science) so only students who wanted to enroll in this course did so.

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

iClicker data were collected as follows. At the beginning of the course, students registered their personal iClicker device with their student ID number via the iClicker website so that all iClicker responses were identifiable. On each class day, iClicker questions were asked (total of 200 questions over 23 days of class, average 8.7 questions per 50 minute class, min = 3, max = 12) and students responded using their iClicker. Students were given ~30 to ~60 seconds to answer each iClicker question and their performance for each question depended only on whether they determined the correct answer and not on how long it took for them to answer the question. The response data were recorded using the iClicker 7.0 software and exported to Microsoft Excel for analysis.

Kahoot! data were collected as follows. During seven non-consecutive days of class, Kahoot! sessions were played using the Kahoot! website (Kahoot! 2018). As Kahoot! is anonymous and not tied to an individual student ID number, students

continued on next page
were allowed to use any name they liked while playing. However, students were encouraged to use the same name every time so that their total points could be tracked since a certificate was awarded at the end of the course to the student who earned the most Kahoot! points. In seven days of class, Kahoot! was used to ask a total of 48 questions (four on one day, six on five days, and 20 on the last day of class). Students were allotted a maximum of 20 seconds to answer each Kahoot! question and their score for each question was proportional to how quickly the correct answer was selected. Students answered the Kahoot! questions using their personal devices (laptop, tablet, or phone) and their responses were recorded along with the number of points earned per question (scale of 0 to 1000, with incorrect answers scored as 0 and correct answers scored from 1 to 1000 depending on how fast the answer was submitted). The response data were then downloaded from the Kahoot! website and exported to Microsoft Excel for analysis.

Since Kahoot! is anonymous, when first analyzing the Kahoot! scores we were unable to match the responses to student ID numbers and thus to exam scores. To aid with this, students were asked to complete an online survey at the end of the course to list the Kahoot! name(s) they had used during the class. Of the 255 students in these classes, 215 students (84%) completed this survey.

To determine student perceptions towards using iClickers and Kahoot! in the human anatomy course, students were asked to complete an online survey at the end of the course. In this survey, students were asked to rate the use of both iClickers and Kahoot! individually as “a fun and an effective way to learn,” “a fun but not an effective way to learn,” “not fun but an effective way to learn,” and “not fun nor an effective way to learn.” Students were also asked to rate how often iClickers and Kahoot! should be used in class “every day,” “once a week,” “once a month,” and “once during the entire class,” and “never.” Students in the Spring 2016 class completed this survey, and of the 127 possible students in the class, 106 students (83%) completed this survey and thus were included in the analysis of perception data.

Data analysis

iClicker data were analyzed as follows: For a given question, student responses were scored as correct or incorrect. Each individual student’s percent correct on iClicker questions was then calculated by dividing the total number of correct responses by the total number of questions that the student responded to and multiplying by 100. To eliminate potential biases of students who only answered a small fraction of the 200 iClicker questions, students had to attend and answer iClicker questions for at least 20 out of the 23 days of class that included iClicker questions. Out of the 255 students in these classes, 211 students (83%) met this condition and thus were included in the analysis of iClicker data.

Kahoot! data were analyzed as follows: Each individual student’s scores on Kahoot! questions were summed and their percent possible Kahoot! score was then calculated by dividing the total number of points earned by the total possible number of points (1000 times the number of questions they responded to) and multiplying by 100. To eliminate potential biases of students who only answered a small fraction of the 48 Kahoot! questions, students had to attend and answer Kahoot! questions for at least 4 of the 7 days of class that included Kahoot! questions. Additionally, students had to provide their Kahoot! name via an end of course survey (described above). Of the 255 students in these classes, 107 students (42%) met this condition and thus were included in the analysis of Kahoot! data.

Once iClicker percent correct and Kahoot! percent possible score were calculated for each student. Multiple linear regression models were constructed to determine possible correlations between these parameters and exam performance in the course. The models included average exam score (as a percentage out of 100) for the four written course exams as the response variable, and iClicker percent correct or Kahoot! percent possible score and college GPA to control for student aptitude. The models were developed using the statistical program R, version 3.1.2 (Team 2014).

Results

Student performance on iClicker questions

Student performance on iClicker questions was compared to their exam performance to determine if there was a relationship between them. As shown in Figure 1, there was a positive correlation between performance on iClicker questions and average lecture exam scores (p < 0.001). To control for student aptitude as a potentially confounding factor, a multiple linear regression model was built that incorporated college GPA as a variable. Even when controlling for GPA, there was a significant positive correlation (p < 0.001) between iClicker performance and exam performance (Table 1). In terms of the model output, on average, when controlling for college GPA, for every one percent increase in iClicker performance there was a corresponding 0.36 percent increase in exam average.

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Student performance on Kahoot! questions

Student performance on Kahoot! questions was compared to their exam performance to determine if there was a relationship between them. As shown in Figure 2, there was a positive correlation between performance on Kahoot! questions and average lecture exam scores. To control for student aptitude as a potentially confounding factor, a multiple linear regression model was built that incorporated college GPA as a variable. Even when controlling for GPA, there was a significant positive correlation ($p < 0.001$) between Kahoot! performance and exam performance (Table 2). In terms of the model output, on average, when controlling for college GPA, for every one percent increase in Kahoot! performance there was a corresponding 0.32 percent increase in exam average. It is worth noting here that the Kahoot! scores included both correctness and speed of answering the question, as opposed to the iClicker performance which only included correctness and was independent of how long it took to answer the question.

### Table 1. Multiple linear regression model summary for average exam performance as a function of iClicker performance. There were significant positive correlations between average exam score (as a percentage out of 100) and iClicker performance. College GPA was included as a control variable for student aptitude. Values for the estimates are provided as the mean +/- the standard error.

<table>
<thead>
<tr>
<th>Regression coefficient</th>
<th>Estimate ± SEM</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model intercept</td>
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<tr>
<td>iClicker score</td>
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<td>6.3e-12</td>
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<tr>
<td>GPA</td>
<td>11.98 ± 1.34</td>
<td>&lt; 2e-16</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
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</table>

### Table 2. Multiple linear regression model summary for average exam performance as a function of Kahoot! performance. There were significant positive correlations between average exam score (as a percentage out of 100) and Kahoot! performance. College GPA was included as a control variable for student aptitude. Values for the estimates are provided as the mean +/- the standard error.

<table>
<thead>
<tr>
<th>Regression coefficient</th>
<th>Estimate ± SEM</th>
<th>p value</th>
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<tbody>
<tr>
<td>Model intercept</td>
<td>21.31 ± 6.36</td>
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<tr>
<td>Kahoot! score</td>
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<td>3.7e-6</td>
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<td>GPA</td>
<td>12.52 ± 1.91</td>
<td>2.18e-9</td>
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<tr>
<td>Adjusted $R^2$</td>
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</table>
Student perception of iClicker and Kahoot! questions
An end-of-course survey was given to determine how students perceived using iClickers and Kahoot! in an undergraduate human anatomy course. When asked about what students thought about using iClickers and Kahoot! in class, somewhat surprisingly, >80% of students reported that iClickers and Kahoot! were both fun and effective for learning (Figure 3A). However, when asked about how often we should use iClickers and Kahoot! in class, >95% of students reported that iClickers should be used every day, whereas ~70% of students reported that Kahoot! should only be used once a week, and a small fraction (~15%) thought it should only be used monthly (Figure 3B).

Discussion
In this study we compared the effectiveness of two types of student response systems (SRSs) in a single undergraduate human anatomy course. We found that student performance on both a traditional system, iClickers, and a gamified system, Kahoot!, were nearly equally predictive of exam scores. Additionally, both systems were rated as equally “fun and effective” by students, but students reported that Kahoot! should be used more sparingly than iClickers. These results have important implications for the implementation of different types of SRSs in undergraduate courses.

We found a significant positive correlation between student performance on iClicker questions with exam performance in an undergraduate human anatomy course. These results agree with prior studies that reported positive relationships between the use of traditional SRSs and exam performance in anatomy and physiology courses (Carpenter and Boh 2008; Alexander et al. 2009). Additionally, we found that students had favorable views towards the use of iClickers, with the vast majority rating them as “fun and effective,” which also agrees with past studies that demonstrated favorable student views towards traditional SRSs in anatomy and physiology courses (Stein et al. 2006; Carpenter and Boh 2008; Wait et al. 2009). This research therefore supports prior findings and future use of SRSs should be considered when designing and teaching anatomy and physiology courses as there are clear benefits to using these systems.

We also found a significant positive correlation between student performance on Kahoot! questions with exam performance that was nearly identical to that between iClicker performance and exam performance. This was at first somewhat surprising, as the Kahoot! questions are scored based not only on correctness but also on how fast the question was answered. Initially we thought that due to the “speed” element of the Kahoot! Questions, the relationship between performance on Kahoot! questions and exam scores would be less strong than that between exam performance and iClicker performance, which is only based on correctness. However, our results suggest that Kahoot! has a positive educational impact since performance on Kahoot! was significantly correlated with exam performance. Thus Kahoot! can be used as a predictive formative assessment tool in the classroom and not just as a “game” that is used to change the pace of flow of a class session. Since the development and adoption of Kahoot! has been relatively recent (the beta version was released to the public in September 2013 (Kahoot! 2018)), there has been limited assessment of this form of gamified SRS and thus limited results to compare with ours. One study has shown similar results. Iwamoto et al. (2017) found that undergraduate psychology students who participated in Kahoot! earned higher exam scores than those who did not participate. While our study and this other study provide support for the positive educational impact of using Kahoot!, additional research is warranted to determine the broader impacts of Kahoot! in undergraduate anatomy and physiology courses.

Since Kahoot! is a gamified form of an SRS, there is the possibility of a “burn out” or “wear out” effect. The concept of “wear out” derives from the advertising industry where frequent exposure to advertisements may result in the loss of effectiveness leading to potential consumers becoming
uninterested in the product (Pechmann and Stewart 1988). With regards to Kahoot!, “wear out” may occur if it is played too often and thus students lose interest and are not as enthusiastic about Kahoot! as they were initially. Indeed, in this study, while we did not measure longitudinal engagement with Kahoot!, we did anecdotally notice that students were not as motivated to play Kahoot! near the end of the course after it had been used multiple times. This result was echoed by Wang (2015) who found that overall student motivation and engagement declined through repeated usage of Kahoot!, most noticeably related to classroom dynamics in terms of how students interacted with each other while playing Kahoot!. This result and ours suggest that careful consideration must be taken when implementing Kahoot! into a course or curriculum so as to not induce “wear out” from high usage rates.

Given our experience of using Kahoot! in an undergraduate human anatomy course, and that Kahoot! is a relatively new type of student response system, we would like to offer the following suggestions for instructors interested in adopting it in their courses. First, because Kahoot! is intended to be used as a “game” with short time limits (ranging from 5 to 60 seconds) we recommend using Kahoot! for lower-level Bloom’s questions such as identification or brief descriptions of structure and/or function. In our experience the shorter the time limit the better (we recommend 10 seconds and no more than 20 seconds per question) since it allows students to very quickly answer questions, thus earning points for correctness and speed. Lower level Bloom’s questions are preferred due to the shortness of the suggested time period. There is also a text character limit for the question stem and answer options, so lengthy stems and options are not allowed by the system.

Second, as described above, there really does seem to be a “wear out” effect of using Kahoot! in a course. While early Kahoot! sessions were received extremely positively by our students, by the end of the course there was noticeably less enthusiasm every time we played (which was only a total of 7 sessions in a 10 week course). Due to this, we recommend playing Kahoot! sparingly, ideally every two to three weeks and at most once a week. In addition, Kahoot! sessions should likely use a limited number of questions (perhaps less than 10) as longer sessions may also lead to “wear out.” If you do play Kahoot! more frequently, we suggest that you use it “randomly” and not on a set schedule (e.g. the start of every Friday class) as this will become routine and it may lose its novelty and effectiveness.

Third, Kahoot! requires students to use their own devices to play (tablet, laptop, or phone) and not all students may have a device. In this case, you can set up the Kahoot! session to allow for teams, or students may simply join in with their classmates to answer questions together using a single device. Lastly, even though Kahoot! is intended be used as a game, it does have educational value as described by the results in our study. Due to this fact, make sure to let your students know that not only is Kahoot! fun but that it also is likely predictive of their exam scores, so the better they do on Kahoot! the better they may perform on exams.

Limitations of the Study
While we demonstrated that student performance on iClicker and Kahoot! questions were equally predictive of exam performance based on multiple linear regression models, we cannot say for certain whether one response system is more valuable than the other in terms of learning or predictive ability for course grades. The reason for this is that different questions were used for each response system and thus we cannot directly compare the performance or predictive capabilities of iClickers and Kahoot! in this study. If direct comparisons are warranted, then identical questions should be used with two different groups of students to determine if there is indeed an advantage or difference between using iClickers versus Kahoot!.

Our survey results showed that students thought that iClickers and Kahoot! were equally “fun an effective”. However they reported that iClickers should be used more frequently (on a daily basis) than Kahoot! (on a weekly to monthly basis). This result may be biased because these were the actual frequencies in which iClickers and Kahoot! were used in the course of this study, so students may have been influenced based on their experience. For a potentially unbiased view, students could be asked about frequency of use at the start of the course before they were exposed to the usage of both systems in the course.

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Acknowledgments
The authors would like to thank the graduate student teaching assistants of this human anatomy course for their dedication to teaching and student learning.

Literature cited


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Comparison of Traditional and Gamified Student Response Systems in an Undergraduate Human Anatomy Course
The Survival of the Physiologist: A Human Anatomy and Physiology Game

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Abstract
Board games continue to increase in popularity and the pedagogical value of games has been repeatedly supported. Games keep students engaged and the level of engagement translates directly into time spent playing, and correspondingly, time spent reviewing course material. Therefore, gameplay is expected to result in greater student success. “The Survival of the Physiologist: An Anatomy and Physiology Game” was developed to involve competition between teams, with opportunities for collaboration among players. Anatomy and physiology students (n=50) rated the game 4.4 ± 0.8 on a scale of 1-5. Educators who played the game at the HAPS workshop (n=41) rated it 3.8 ± 0.8. Additionally, beta tester educators (n=4) rated it 4.5 ± 0.9 in their own classrooms. Ninety-one percent of students surveyed and 82.9 percent of educators rated it a good tool for learning the material of anatomy and physiology. Among the HAPS educators at the workshop, question coverage was ranked at 4.4 ± 0.8 with 90.2% of them indicating the level of difficulty was just right. Currently we are discussing developing a computer version of the game. https://doi.org/10.21692/haps.2019.006

Key words: educational board games, active learning, cooperative learning, anatomy & physiology

Introduction
Beginning in the 1980’s, much pedagogical emphasis has been placed on active learning and cooperative learning (Faust & Paulson 1998). The caveat is that increased time and effort are required to do these methodologies well. However, such effort is fruitful in that student academic success has been definitively linked to the introduction of interactive learning, including game play, into the teaching panoply (Montrezor 2016).

The context of game play (classroom/home; in person/online) affects its efficacy for learning (Aburahma and Mohamed 2015). In 2011, Sauve et al. reported on a systematic review of studies highlighting the game elements that support motivation and learning. These included repetition, learning, content segmentation, feedback, challenge, competition, active participation, teamwork, and interaction. Janssen et al. (2015) found that teamwork especially was found to enhance enjoyment, length of play time and, thus, retention. The game presented in the current paper contains elements of all of these factors.

It has been demonstrated that computer games, which use action rather than explanation, communicate complex ideas and reinforce mastery of concepts (Charles and McAlister 2004; Holland et al. 2002). They are particularly effective because of their accessibility to students with various learning styles.

Undergraduate students in upper level classes are more likely to engage in productive collaborative study than those in lower level classes (Ventimiglia 1994). Thus, this game was designed to have sufficiently challenging elements to maintain student interest, what Linn et al. (2010) describe as “desirable difficulties”. Game tactics use whole-class collaboration and within-class competition. Competition has been found to enhance learning (Nuland et al. 2014; Sauve et al. 2011). Our goal was to create an interactive review game for anatomy and physiology students taught at a level appropriate to our course objectives.

Materials & Methods
The Premise of the game
Players (the class) represent survivors of an apocalyptic event. They are trying to reach a location with the hope of finding other survivors and more permanent food and lodging. To get to “civilization”, survivors must traverse four different environments and face the challenges of each environment.

Game Pieces
Six-sided dice (one per player). The rolled value represents health status for the start of the game, with 6 being healthiest and 1 least healthy. Health status is altered during the game.
based on food and water availability and conditions found in each environmental challenge.

**Team markers** (we used brain-shaped erasers). These are used to mark progress along game board environments.

**Non-perishable food tokens** (we used beans). Each team starts with two. Players may use these to survive low food situations and may add them to supplies according to directions on individual environment boards.

**Attribute cards** (list skills, talents and issues). One or two are dealt to each player at the onset of game play. The attribute will determine ability of players to access food and water, survive challenges, and avoid loss of health (Figure 1).

**Hexagonal environments** (serve as the game board). Environments have a central pictorial representation of the habitat. They also have a series of “squares” around the periphery that players proceed along as they answer questions from a card pack. At the end of a turn, the square landed on may be blank, have additional challenges, or present consequences which affect food, water or health status (Figure 2).

**Hexagon completion token** (awarded each time a team completes a hexagonal environment). These count as points in the final game tally.

**Death token** (black chips “awarded” to each team if a player is lost to death). These count as negative points in final game tally

**Tools tokens** (represent individual tools, such as knife, rope or fishing pole that can be used creatively by team members to meet environmental challenges). Tool tokens are placed upside-down on the playing surface, and each team gets one tool at the onset of play. Tools are returned to the pile upside-down after use. More tools can be gained by landing on appropriate environmental spaces.

**Food and water resource dice** (Sixteen dice, color-coded for perishable food (green), non-perishable food (brown), water (blue) and no survival resource (silver). Each six-sided die has two green faces, two blue faces, one brown face, and one silver face. These are rolled at the end of each turn to determine resource status.

**Group question cards** (400 questions covering both anatomical and physiological aspects of Anatomy and Physiology). Survivor groups may answer without multiple choice options and progress two squares for each correct answer, or opt for multiple choice and progress only one square for a correct answer (Figure 3A).

**Individual question cards** (One member of a team landing on an individual question square at the end of their turn must answer an individual challenge question). Individual challenges involve deeper conceptualization and application of knowledge as opposed to simple memorization. A correct answer moves the team ahead one space (Figure 3B).

**Whole-class question challenge cards** (used when a team lands on a whole-class challenge question square at the end of their turn). All class members work together to answer it. A correct answer moves all teams forward one square. Whole class challenges are designed to encourage collaboration, and they require a greater wealth of information about a single system. Examples include naming all of the carpal bones, or listing the capillary beds of the kidneys with associated nephron segments (Figure 3C).

**Healer:** This card can be used once to replenish one team mate back to full health points. After use discard and draw a new Attribute card.

**Allergic:** You have food allergies which require your team to throw out one non-perishable food unit each turn.

**Egotistical:** Your team has no choice; you answer all of the individual challenge questions.

*Figure 1. Attribute card examples*
The Survival of the Physiologist: A Human Anatomy and Physiology Game

Find high protein lizard

Gain two health points

TAKE A TOOL

INDIVIDUAL CHALLENGE

Get sand in your shoes and lose one health point

Desert – in this environment you will need 6 waters and 9 foods per turn

TRADE

INDIVIDUAL CHALLENGE

Find high protein lizard

Gain two health points

TAKE A TOOL

GROUP CHALLENGE

Take a toboggan and move ahead two spaces

The water you saw was a mirage. Go back two spaces or lose three health points

Cold nights – if protected move ahead one

If not lose two health points

Which type of bone development starts with a cartilage model?

- Appositional
- Endochondral
- Intramembranous
- Spongy

Which three organ systems cooperate to produce voluntary locomotion?

- Skeletal
- Muscular
- Nervous

Name all of the cranial bones.

- Sphenoid
- R&L Parietal
- Occipital
- Frontal
- Ethmoid,
- R&L Temporal

Figure 2. Hexagon environment prototype.

Figure 3. Examples of A. Group question card, B. Individual question card, C. Whole class question card.
Instructions
At the onset of the game, each team of 3-5 players turns over their first hexagon and places a team marker on the starting square.

Each individual player rolls a numbered die to obtain initial health status. The team with the highest total health points goes first and the play proceeds clockwise.

Each team will have 90 seconds to answer as many questions as they can answer correctly. Alternately, the instructor can limit the number of questions per turn. Either the instructor or a member of another team draws a question card from the top of the Team Card pile. The team marker is moved as described under “Group question cards”. A card cannot be skipped unless the instructor removes it. In the case of incorrect answers, the card is set aside until the end of their turn.

The team will follow the directions only on the square they land on at the end of the turn. If the consequences of the square redirect them to another square they do not follow the directions on the new square.

At the end of their turn, the team rolls the food and water resource dice and tallies their obtained resources:
- Green – Perishable Food
- Brown - Non-perishable Food
- Blue – Water
- Silver – No resource

The total of food resources must meet the environment requirement.
- If brown total exceeds required resources, an equivalent number of non-perishable food tokens are awarded to the team.
- If food count falls short of the requirement, teams can use non-perishable tokens to make up the missing food.
- If they cannot meet the food requirement, they lose one health point from any group member for each insufficiency.

The total water resources must be met.
- For every water resource not met, the team sacrifices one health point from the player of their choice.
- If they have excess water and a tool to carry it in, they may use it at a later turn.

At the end of each turn, survivors must have a health status greater than zero or that team member dies. When a team member dies, the black token is awarded and the “dead” player’s attribute card(s) and health die are returned. The student takes on the role of a new survivor that joins the team (and gets new health and attribute card(s) at the start of the next turn.

If the team completes an environment hexagon, the team gets a marker and they turn over another hexagon and move to the new environment. The environment they have completed is returned upside down to the available environments pile. That team’s turn ends when it gets the new hexagon and their team marker is placed in the starting position.

Questions incorrectly answered, which were held in reserve, can be “stolen”. The instructor will reread the card, including the multiple choice hints; the first person raising their hand answers. If correct, their team advances one space on their own hexagon. If incorrect, their team goes back one square.

The End
Once any one team has completed four environments the game ends.

Scoring final tally
- Each hexagon completion token = 6
- Each tool still in possession at the end = 2
- Each non-perishable food or water resource at the end = 1
- Each black death token = -4

Variations
Instructors are encouraged to modify the game to best suit their needs. Game play can be arranged as review of a single topic as part of a lab; or as a review for a quiz or test covering many topics in lieu of lab or outside of lab. It could be included for a specified time in each lab, or used only occasionally.

Assessment
The “Survival of the Physiologist” game play was introduced in our Anatomy and Physiology I (n=16 students), Anatomy and Physiology II (n=26), and Medical Physiology II (n=8) classes, in the spring semester of 2018, as a portion of a scheduled laboratory activity. Students in our classes (n=50) were given a pre-test consisting of 10 multiple choice questions prior to game play which were developed by faculty at Ohio Northern University (ONU) based on course content goals; and the same 10 questions were used as a post-test following game play. Following the first time the game was played, students were surveyed using a paper-based anonymous survey. The survey asked students to grade the game on a scale of 1-5 where 5 = A and 1 = F: “Was the game fun?”, “Please rate game clarity”, “Please rate game design/aesthetics” and “Give the course an overall grade”. It also asked students as a yes/no question, “Did this help you learn the course material?” After the initial day of game play, students voluntarily played the game during subsequent laboratories as a time-filler while experiments were running.
Because this game was so popular with students, it was presented as a workshop at the 2018 Human Anatomy and Physiology Society (HAPS) Annual Meeting in Columbus, OH (Motz et al. 2018). Approximately sixty people were in attendance. This far exceeded expectations; the room was crowded and noisy, and it was not possible to distribute rules to all participants. As a result, game play was set up for two groups with more players than recommended so everyone could participate. Following game play, forty-one of the attendees filled out evaluations grading the game for fun, clarity, and aesthetics on a scale of 1-5 where 5 = A and 1 = F. Participants also were asked if they felt the game was a good learning tool as a yes/no question, whether they felt the question level was too easy/just right/too difficult, and whether they wanted to participate as beta testers for the game. For all data, the number scale mean scores standard deviation were calculated.

Game boards, directions, game pieces and the same pre and post-test questions we used at ONU were provided to those who indicated an interest and were able to test the same two systems (muscular and skeletal) during the fall semester 2018-19 in their college classes.

Based on student surveys, our own observations, and helpful comments from beta testers, modifications were made and development of an online version and patent is in progress.

Results
The first time the game was played in our classes, at the HAPS meeting, and in beta test situations, there was a learning curve as to how play proceeded and how the game cards were utilized. Length of time spent playing was variable based on lab time available. Three rounds of play was possible at a minimum, and on other occasions students played for up to an hour. When students had the opportunity to play the game, and when Anatomy and Physiology II students who had played in Anatomy and Physiology I played again in the following semester, play moved more quickly each time it was played, as familiarity with the rules increased. Student enjoyment appeared (anecdotally) to increase as ease of play improved with particular enjoyment centering on the attribute cards and health status dice.

Student response to the game
Student ratings of the game following the first time it was played, for fun, clarity, and aesthetics on a scale of 1-5 where 5 was best, had a mean overall rating for Anatomy and Physiology I, Anatomy and Physiology II and medical physiology students of 4.4+/−0.8 (Figure 4).

Additionally, students were asked whether or not they felt the game was a good learning tool. Ninety-one percent of students rated the game as a valuable tool to promote student learning (Figure 5).
**HAPS participant response to the game**

Overall, the HAPS attendees who filled out surveys rated the game 3.78 ± 0.78 on a scale of 1-5 (Figure 3). In terms of being fun to play, it was rated 4.04 ± 0.88. Question content received an excellent rating of 4.39 ± 0.77. Ninety percent of respondents considered the questions to be at the right level of difficulty, with 7% finding them too difficult and 2% rating them too easy. Eighty-three percent of respondents felt the game was a good learning tool and 48.7% expressed an interest in beta testing the game in their class. The biggest criticism of the game was that the rules were fairly complicated. Clarity of play was rated at only 2.9 ± 1.1 (Figure 6).

**Beta tester response to the game**

The muscular and skeletal system questions were chosen for beta-testing using two environmental hexagons in six classes taught by four educators. Rather than providing all of the game pieces, game progress was tracked on a score sheet. Two educators played it only once with their classes, one played it twice and one played it three times. Educators administered a pre-test before the first game play and an identical post-test after that session as described above. Mean scores (± standard deviation) improved 10.7 ± 3.3% from a pre-test score of 62.5 ± 4.5 to a post-test score of 73.2 ± 6.6. Before game play only 32.1 ± 13.9% of students scored above a 70% whereas after game play 79.5 ± 16.9% of students scored above a 70%. Participating faculty rated the game for: its effectiveness as a review (teaching) tool, student enjoyment, game design, aesthetic appeal, question difficulty, and coverage. They also assigned an overall score. All mean scores were between 4.3 and 4.5 for all parameters (Figure 7).

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**Figure 6.** Ratings on a scale of 1-5 of game aspects (where 5 = A and 1 = F) by faculty attending the workshop at the 2018 HAPS meeting (n=41). Error bars indicate standard deviation.

**Figure 7.** Ratings by Beta testers (n=4) on a scale of 1-5 (where 5 = A and 1 = F). Error bars indicate standard deviation.
Feedback from Beta-testers indicated that the learning curve for the game was steep due to its complexity. The two educators who used the game more than once ranked it more highly than the two who used it only once. The “attributes” were cited as contributing largely to student enjoyment of the game, while counting beans and food points were less enjoyable aspects. The use of individual questions vs. team questions vs. whole class questions was the most controversial item. One tester explained that some questions were looking for interaction between multiple systems and not all of the material had been covered in class yet. Beta testers liked the coverage and question level; one beta-tester indicated that they would like to have a version of easier questions available to use with a lower level class.

Discussion
Based on surveys of students and educators, “The Survival of the Physiologist: A Human Anatomy and Physiology Game” was deemed to be an enjoyable and effective learning tool for undergraduates taking anatomy and physiology courses. This is in keeping with many studies indicating that interactive game play increases learning success (Anyanwu 2014; Cain et al. 2014; Montrezor 2016). Based on student and educator feedback, some simplification of game mechanics would improve student enjoyment and decrease the steepness of the learning curve. The beta-testers were given score sheets that could be used to track health, and it is likely that we should expand this score sheet to track food, water and tools. Not only would it make playing the game easier as a board game, but it would also improve its projected development as a computer game. We are considering converting it into an electronic form since there is a large body of evidence supporting video games as effective delivery systems for knowledge acquisition (Boyle et al. 2016).

Conclusion
Game play can be an effective tool to reach students of various learning styles both as board games and as video games. “The Survival of the Physiologist: A Human Anatomy and Physiology Game” game has promise as an educational resource and should be developed for general distribution.

Acknowledgements:
We are grateful to HAPsters who attended our workshop, to our beta-testers for taking the time to pilot our game in their classrooms and to provide formative feedback, and to our students for their tolerance during game development.

About the Authors
The authors are faculty members in the Department of Biological and Allied Health Sciences, Ohio Northern University who are actively involved in the use of interactive learning in their teaching methodologies. All authors teach in the full year cadaver-based human anatomy and physiology sequence geared toward nursing and exercise physiology majors. Additionally, Drs. Motz and Suniga and Bennett-Toomey team teach a year-long physiology course geared toward pre-meds, pharmacy majors and upper level allied health students, and Drs. Connour and Koneval teach anatomy courses.

Literature cited


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The Value of Traditional Lecture in Medical Gross Anatomy: Student Perceptions and Performance

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Abstract
This study examines gross anatomy students' perception of lecture and the value of lecture based on student performance. Following a single lecture, students (n=85) completed a questionnaire asking about their perceptions of lecture using a 1(low) – 10(high) rating scale and a five question, multiple-choice quiz. Students later answered these questions on the block exam. Students rated how much they learned during traditional lecture (m=5.24 ± 1.7), how much lectures guided their study (m=6.78 ± 2.1), and importance of lecture attendance (m=6.48 ± 2.2). Recall on the post-lecture quiz was poor (52.47% ± 26.5) but significantly improved on the exam (85.65% ± 21.7); z= -6.91, p<0.0001. This indicates that students who attended the lecture place intermediate to high value on some aspects of lecture, but do not immediately recall lecture information. This implies a disconnect between students perceptions of lecture and the benefits they may actually receive from lecture attendance.

https://doi.org/10.21692/haps.2019.004

Key words: anatomy education, lecture, student perceptions, immediate recall

Introduction
In the most recent AAMC Curriculum Inventory Report on instructional methods used in medical school, lecture was reported as the most commonly used method to present material, accounting for 55% of all medical education events (AAMC). The second most common instructional method, small group discussion, was used for only 5.5% of events. Given that a lecturing instructor is limited only by the speed at which they speak (Di Leonardi 2007), lecture may be perceived as the most efficient way to deliver information to a large group of students (Schwartzstein and Roberts 2017). As the hours allocated to teach medical gross anatomy continue to decrease (McBride and Drake 2018), efficiency remains a priority in anatomical education.

In addition to the perceived efficiency of lecture, some evidence suggests that students generally like lecture and the specific benefits it may provide. In a study that asked how much material should be taught through lecture, approximately 60% of medical students felt that at least 60% of content should be taught using this method (Tsang and Harris 2016). Lecture was also ranked in the top five preferred methods of teaching by 94.5% of first year medical students (Zinski 2017). Another group of preclinical medical students rated lecture and practical notes as the number one self-study resource (Choi-Lundberg et al. 2016). This evidence suggests that medical students continue to perceive value in the lecture method.

While lecture attendance is a major concern for many instructors (Schmidt et al. 2015; Young 2008), students have reported several reasons for wanting to attend lecture. Reported reasons include: lectures provide exam guidance and big picture concepts (Khong et al. 2016), important concepts are emphasized (Bati et al. 2013), there is a social expectation to be present (Eisen et al. 2015), in order to show professionalism (Cardall et al. 2008), and the ability to ask questions in real time (Bati et al. 2013; Cardall et al. 2008). Perhaps most importantly, students have reported that they learn well in the lecture setting and attend lecture for this reason (Eisen et al. 2015).

Despite medical students having positive perceptions of lecture, this method also suffers many criticisms. Lecture is often referred to as a passive method of teaching which encourages memorization and regurgitation of facts, rather than promoting critical thinking (Schmidt et al. 2015), problem solving skills, communication (Lujan and DiCarlo 2006), or life-long learning (Tsang and Harris 2016), all of which can be critical to success as a future healthcare provider. As far back as 1910, the Flexner Report suggested that the traditional lecture method used in medical education did not allow students to apply information or provide opportunities to develop a professional identity (Irby et al. 2010).

Because of the shortcomings associated with lecture, there is a movement in medical education toward more student-centered classrooms. This approach places students at the center of the learning process (Estes 2004) by using class time for active learning through discussion and practicing the application of information (DiPiro 2009; Prober and Heath
During most lectures, basic science faculty presented lectures, laboratory dissections, and group activity sessions. Anatomy was twelve credit hours and consisted of traditional laboratory dissections, students in the fall semester. The course was taught using a PowerPoint (Microsoft Corporation, Seattle, WA: Microsoft) to deliver content. Lecture attendance was mandatory when given by clinicians, and encouraged when given by basic science faculty. All lectures were recorded and were available for students to view throughout the year. For dissection laboratories, students were put into groups of eight (2017) or six (2018). Each group was then further divided into group A and group B. Responsibility for completion of the dissection alternated between group A and B. Weekly group activity sessions included worksheets, games, and practice questions to review material covered that week. Students were assigned weekly readings from the required textbook (Gray's Basic Anatomy, Drake et al, Elsevier, 2nd Edition), but there were no checks for completion. Final grades in the course were derived from four block exams that included a multiple choice written exam and a practical exam (80%), radiology quizzes each block (5%), weekly group quizzes (5%), and board exam scores (10%).

During the years of 2017 and 2018, medical school students were invited to participate in the study during the second week of medical gross anatomy after a basic science faculty member delivered a lecture on the spinal nerve. Objectives of the lecture were for students to demonstrate an understanding of:

1. The organization of the spinal cord.
2. Components of a spinal nerve.
3. The functional components of a spinal nerve.
4. The sympathetic innervation to the spinal nerve.

Methods

Study Context
The University of Mississippi Medical Center (UMMC) is a large academic medical center in the southeastern United States which upholds an educational mission to train future healthcare providers through the schools of medicine, dentistry, pharmacy, nursing, allied health science, and graduate studies. The medical school typically only accepts in-state residents and is the state’s only allopathic program. The curriculum includes two years of basic science training followed by a two-year clinical phase. In the first year of medical school Gross Anatomy, Histology and Cell Biology, Developmental Anatomy, Biochemistry, Physiology, Neuroscience, and Introduction to the Medical Profession are taught as separate courses.

In 2017 and 2018, gross anatomy was taught to first year students in the fall semester. The course was taught using a regional approach and was divided into four blocks starting with back and upper limb, then thorax and abdomen, pelvis, and lower limb, and head and neck. During the study, gross anatomy was twelve credit hours and consisted of traditional lectures, laboratory dissections, and group activity sessions. During most lectures, basic science faculty presented overview material and discussed complex anatomical areas. Clinicians also presented lectures that focused on connecting anatomical information to clinical practice. Both groups of presenters had fifty minutes per lecture and primarily utilized PowerPoint (Microsoft Corporation, Seattle, WA: Microsoft) to deliver content. Lecture attendance was mandatory when given by clinicians, and encouraged when given by basic science faculty. All lectures were recorded and were available for students to view throughout the year. For dissection laboratories, students were put into groups of eight (2017) or six (2018). Each group was then further divided into group A and group B. Responsibility for completion of the dissection alternated between group A and B. Weekly group activity sessions included worksheets, games, and practice questions to review material covered that week. Students were assigned weekly readings from the required textbook (Gray’s Basic Anatomy, Drake et al, Elsevier, 2nd Edition), but there were no checks for completion. Final grades in the course were derived from four block exams that included a multiple choice written exam and a practical exam (80%), radiology quizzes each block (5%), weekly group quizzes (5%), and board exam scores (10%).

Data Collection
Procedures were carried out according to the protocol approved by the Institutional Review Board of the University of Mississippi Medical Center (IRB # 2017-0201) and informed consent was obtained from all participants. Immediately following the spinal nerve lecture, students were approached by the first author, who was not associated with the course in any way, and asked to participate in the study. After a verbal introduction to the study, students were given a paper packet with an informational letter detailing the requirements of participation, a questionnaire (see appendix), and a quiz. Students that chose not to participate were still given the option to complete the quiz for practice, but were asked not to complete the questionnaire. All questionnaires and quizzes were collected after completion, regardless of student participation. Only students who completed both the questionnaire and quiz were included in analysis.

The questionnaire was used to assess students’ perceived value of lecture and to determine how students preferred to learn. Students were asked to rate the first three items using...
The Value of Traditional Lecture in Medical Gross Anatomy: Student Perceptions and Performance

a rating scale of 1 (low) to 10 (high). The first item on the questionnaire asked students to rate how much they felt they learned during traditional lecture (1=I learn nothing at all; 10=I learn everything I need to know). The second item asked how much lectures guide their study and preparation for exams (1=Not at all; 10=Very much). The third item asked how important it was to attend lectures (1=Not at all; 10=Essential). The questionnaire also included two open-ended items asking how they preferred to learn about anatomy or a topic other than anatomy when given fifty minutes to do so.

The quiz consisted of five multiple choice questions about material from the spinal nerve lecture and was identical for the 2017 and 2018 classes. These questions were selected from gross anatomy exams from previous years. Four of the questions were considered first order and one was considered second order. Students were made aware that the quiz had no effect on their course grade but were asked to give their best effort. Three weeks later, students took the block one gross anatomy written exam consisting of approximately 80 single answer multiple choice questions. Of the 80 questions, five were spinal nerve questions relating to content from the spinal nerve lecture. For the 2017 class, four questions were identical to the questions on the post-lecture quiz while one was on the same content area. For the 2018 class, all five spinal nerve questions on the block examination were identical to the post-lecture quiz.

**Analysis**

Demographic data and student ratings were reported using descriptive statistics including mean, median, and standard deviation. A one-sample t-test was used to analyze if there was a significant difference between the average student rating for each item and a hypothetical mean of the 1-10 scale (5.5 out of 10). Wilcoxon signed-rank tests were used to determine if there were any significant differences between performance on the post-lecture quiz and performance on spinal nerve questions on the block one exam. Significance for all analyses was set at p<0.05 and all statistical analysis was completed using Stata (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC).

For the open-ended items, the first author assigned codes by identifying the activities that students reported as their preferred method of learning. For example, a response stating, “I would look over PowerPoint slides and then read the book”, was coded as “PowerPoint” and “Read”. These codes were tallied to obtain frequency counts.

**Results**

Of the 160 medical students in the 2017 class, 72 (45.0%) students attended the spinal nerve lecture and 49 (30.6%) students completed the questionnaire. There were 167 students in the 2018 class with only 48 (30.0%) attending the spinal nerve lecture and 41 (24.6%) completing the questionnaire. Three students in 2017 and two students in 2018 had incomplete data and were excluded from analysis, leaving a combined total of 85 students with complete data (Table 1).

**Table 1.** Demographic information for all students included in analysis. Participants are reported as the number of students that took part in the study and as a percentage of total medical students in the given year.

<table>
<thead>
<tr>
<th></th>
<th>2017 (28.8)</th>
<th>2018 (23.4)</th>
<th>Combined (26.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>20 (43.5)</td>
<td>13 (33.3)</td>
<td>33 (38.8)</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>26 (56.5)</td>
<td>26 (66.6)</td>
<td>52 (61.2)</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>23.46 ± 2.6</td>
<td>23.77 ± 2.5</td>
<td>23.60 ± 2.6</td>
</tr>
<tr>
<td>Range</td>
<td>21 – 34</td>
<td>21 – 31</td>
<td>21 – 34</td>
</tr>
</tbody>
</table>
The Value of Traditional Lecture in Medical Gross Anatomy: Student Perceptions and Performance

**Table 2.** Student ratings of questionnaire items. \( a = \) how much you learn during a traditional 50 minute lecture; \( b = \) how much lectures guide your study and preparation for course exams; \( c = \) how important it is to attend lectures. All items were rated on a scale of 1-10, with 1 being low and 10 being high.

<table>
<thead>
<tr>
<th></th>
<th>Learn During Lecture ( a )</th>
<th>Lecture Guides Study ( b )</th>
<th>Importance of Attendance ( c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 (M±SD)</td>
<td>4.89 ± 1.7</td>
<td>6.40 ± 2.2</td>
<td>6.04 ± 2.3</td>
</tr>
<tr>
<td>2018 (M±SD)</td>
<td>5.67 ± 1.6</td>
<td>7.30 ± 1.9</td>
<td>7.00 ± 1.8</td>
</tr>
<tr>
<td>Combined (M±SD)</td>
<td>5.24 ± 1.7</td>
<td>6.78 ± 2.1</td>
<td>6.48 ± 2.2</td>
</tr>
</tbody>
</table>

Student perceptions concerning the value of traditional lecture are shown in Table 2. One-sample t-tests show there was not a significant difference between students rating of how much they learn during lecture and the midpoint of the scale; \( t(84) = -1.39, p=0.1676 \). However, ratings for how much lecture guides study and preparation for exams and ratings for the importance of attendance were both significantly higher than the midpoint of the scale (hypothetical mean of 5.5); \( t(84) = 5.61, p<0.0001 \) and \( t(84) = 4.21, p<0.0001 \), respectively.

For the open-ended items, the highest number of students indicated a preference for reading to learn a topic in anatomy (40 out of 85 respondents, 47.8%) or a topic other than anatomy (38 out of 85, 44.7%). Only four (4.7%) of the respondents indicated that they preferred to attend a lecture in order to learn about a topic in anatomy. Additional responses to these items are shown in Table 3 and Table 4.

**Table 3.** Top 10 reported methods of learning about a topic in anatomy when students are given 50 minutes. Open ended items were coded and reported as frequency counts.

<table>
<thead>
<tr>
<th>Top 10 Reported Methods of Learning Anatomy</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read</td>
<td>40</td>
</tr>
<tr>
<td>Study Diagrams/Charts/Tables</td>
<td>14</td>
</tr>
<tr>
<td>Study PowerPoint Slides</td>
<td>12</td>
</tr>
<tr>
<td>Watch Videos/Animations</td>
<td>11</td>
</tr>
<tr>
<td>Study an Atlas</td>
<td>11</td>
</tr>
<tr>
<td>Self-test/Practice Questions</td>
<td>11</td>
</tr>
<tr>
<td>Create Outline/Take Notes</td>
<td>6</td>
</tr>
<tr>
<td>Draw</td>
<td>6</td>
</tr>
<tr>
<td>Use Flashcards</td>
<td>5</td>
</tr>
<tr>
<td>Attend a Lecture</td>
<td>4</td>
</tr>
</tbody>
</table>

The 2017 class scored an average of 48.26% ± 28.8 on the post-lecture quiz with a median score of 40%. The average exam score for the five spinal nerve questions was 89.13% ± 18.2 with a median score of 100%. Compared to the post-lecture quiz, exam scores for the five spinal nerve questions were significantly higher (\( z=-5.56, p<0.0001 \)). The 2018 class scored an average of 57.44% ± 23.0 on the post-lecture quiz with a median score of 60%. The average exam score on the five spinal nerve questions was 81.54% ± 24.9 with a median score of 100%. Compared to the post-lecture quiz, exam scores for the five spinal nerve questions were significantly higher (\( z=-4.05, p<0.0001 \)). The combined average for the two years on the post-lecture quiz was 52.47% ± 26.5 with a median score of 40%. Performance on the spinal nerve exam questions was significantly improved with an average of 85.65% ± 21.7 and a median score of 100% (\( z=-6.91, p<0.0001 \)).
Discussions

This study attempts to better understand both gross anatomy students' perception of lecture and the value of lecture based on student performance. Our first hypothesis was that students who attend a given lecture will highly rate items associated with a perception of value in lecture and report a preference for learning by attending lecture. The results from the questionnaire indicate that this was only partially correct. The first item asking how much students felt they learned during lecture was not significantly different from the midpoint of our scale, indicating that students had an intermediate opinion as to the amount they actually learn in a given anatomy lecture. This is somewhat surprising since studies have reported that students feel they learn a great deal from lecture (Covill 2011) and even reported learning more in lecture than in active learning sessions (Lake 2001).

The second item asking students how much lecture guides their study and preparation for examinations was rated significantly higher than the midpoint of the scale. This suggests that students see some value in the lecture for this purpose. This is in line with prior studies that emphasize using lectures as a guide for study. For example, Choi-Lundberg et al. (2016) found that first year medical students rated lecture notes as the number one resource for studying. Some students have reported that they attend lecture because lectures emphasize important topics (Bati et al. 2013; Brawer et al. 2015) and provide exam guidance (Khong et al. 2016).

The final item rated by students was concerning the importance of lecture attendance. Students rated this item significantly higher than the midpoint of our scale. However, it is also important to note that between the two years, only 37% of enrolled students actually attended the spinal nerve lecture, which took place in the second week of the first year of medical school. While attendance at other medical schools may vary substantially, some have reported that it begins high and then declines. Mattick et al. (2007) found that medical student attendance dropped steadily throughout the first semester and then leveled off at about 57% halfway through the first year. Gupta and Saks (2013) reported that first year medical students attend 75% of lectures but by the second year students attended only 50% of lectures. Second year medical school attendance has even been reported as low 33% (Eisen et al. 2015). For the current study, it is surprising that only 37% of students attended a lecture that took place so early on in the first year, potentially indicating that the students overall had a low perception of the importance of lecture attendance.

Our second hypothesis was that students that attend a given lecture have poor immediate recall of lecture material but are able to adequately learn the lecture material for course examinations given at a later date. This hypothesis is supported by students' performance on the post-lecture quiz and spinal nerve questions on the exam. Between the two years, average immediate recall on the post-lecture quiz was 52.5% (2.62 out of 5). This is comparable to other studies which have reported immediate recall scores on post-lecture quizzes at 53.8% (Wong et al. 2007) and 66.7% (Alluri et al. 2016). However, performance on the exam was significantly improved, indicating that with the current traditional lecture much of the content learning occurs outside of class between the lecture and exam. While it is outside the scope of this study, it may be important to determine how students use the lecture to guide their preparation for course exams. While students may not have learned directly from attending a lecture, it may have put them in a better position to learn outside of lecture when compared to classmates who did not attend.

Results of this study suggest a disconnect in student perceptions of the value of lecture. Students gave intermediate to high ratings of items associated with a perception of value in the lecture method but when asked for a preferred method of learning, few students actually reported that they would like to attend a lecture. Coupled with poor recall immediately after a given lecture, these findings indicate a possible need for change in the traditional lecture method. Many sources offer advice on ways to improve the traditional lecture and potentially increase knowledge retention (Matheson 2008; Singh and Kharb 2013; Wolff et al. 2015). Some suggestions include incorporating opportunities for students to process information by introducing questions to stimulate small group discussions (Di Leonardi 2007) or integrating activities such as think-pair-share, concept mapping, or guided reciprocal peer questioning (King 1993). Alternatively, flipping the classroom may offer another approach to improving perceptions and performance. This method facilitates initial content learning outside of class, while scheduled class time can be used to discuss difficult concepts and practice the application of information (Schwartzstein and Roberts 2017).

There are several limitations of the current study. Only students who attended the spinal nerve lecture were invited to participate in the study. Students who did not attend may have rated questionnaire items differently and performed differently on the post-lecture quiz. However, the ratings of items concerning student perception of lecture were not high and immediate recall was poor, even by those who valued lecture enough to attend. Secondly, no baseline quiz was given prior to the lecture. This was in an effort to maintain an authentic lecture experience and avoid cuing students to attend to certain information from the lecture. Because of this, we are unable to determine the amount of knowledge increase that occurred during the lecture. Students were also made aware the post-lecture quiz had no effect on their grade, while the exam questions did, meaning that students may not have attended to the post-lecture quiz in the same way. Additionally, the current study considered just one lecture topic presented by one faculty member for two
consecutive years. There are a number of factors that vary across traditional lectures and therefore these results may not be generalizable across all lectures. Future research should consider student perceptions and outcomes over a range of topics and lecturers. Finally, while there was a significant improvement in scores between spinal nerve questions on the post-lecture quiz and the block exam, it remains unknown what specific resources and techniques these students used to improve their performance and further research may explore these questions.

Conclusion

Literature indicates that students maintain a positive perception of lecture, however there are many critics of this method. The current study found that while students attending a medical gross anatomy lecture gave intermediate to high ratings of items associated with placing value on lecture, they did not often report lecture as their preferred method of learning. Additionally, students that attended a given lecture had poor immediate recall of material covered in lecture, but were able to perform adequately on spinal nerve questions on the block exam. This suggests a possible need for change in the traditional lecture method. By identifying the actual benefits of lecture, instructors may be able to move away from using lecture only as a content delivery method and focus more using lecture as a guidance tool that helps students learn outside of assigned contact hours.

About the Authors

Sara Klender, BS, is currently a third-year graduate student in the Clinical Anatomy program at the University of Mississippi Medical Center (UMMC) in Jackson, Mississippi. Her research interests include the evaluation of lecture as a teaching method and the impact of fear of death on performance in gross anatomy courses.

Andrew Notebaert, PhD, is an assistant professor at the University of Mississippi Medical Center (UMMC). He also serves as the Program Director for the PhD in Clinical Anatomy at UMMC. He teaches education-based courses to graduate students and conducts research on student perceptions of learning in anatomy and in medical school.

Literature cited


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Young JR. 2008. The lectures are recorded, so why go to class? Chron High Educ. 54(36):A1.

– APPENDIX –

Participant Survey

Name: _______________________________________
Age: _______________________________________
Program of Study: ___________________________
Sex (circle one): M  F

In regards to what you need to know for course exams, please rate (on a scale of 1-10) how much you learn during a traditional 50-minute lecture.

1 = I learn nothing at all  10 = I learn everything I need to know

On a scale of 1-10, please rate how much lectures guide your studying and preparation for course exams.

1 = Not at all  10 = Very much

On a scale of 1-10, please rate how important it is to attend lectures.

1 = Not important at all  10 = Essential

If you are given 50 minutes to learn about a topic in anatomy, how would you spend this time?

If you are given 50 minutes to learn about any topic other than anatomy, how would you spend this time?
Why Do Science Students Study Physiology? Career Priorities of 21st Century Physiology Undergraduates

Julia Choate, PhD1 and Harrison Long2

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2Biomedical Program, Monash University, Victoria 3800, Australia
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Abstract
There have been significant increases in the number of students studying physiology in the Bachelor of Science degree-program at our university. We thought that physiology prerequisites for graduate programs in medicine and allied-health areas were facilitating these increased numbers. Undergraduate physiology students were surveyed about their career priorities: 25% were undecided/uncertain; 22% intended to study graduate medicine; 15% wanted to get a job straight after their degree; 10% planned to study in an allied-health area. Their careers uncertainty remained high, even in their final semester, suggesting a critical need for in-curriculum careers education. With 32% of students selecting graduate programs in medicine or allied-health, this supports the idea that elevated student enrolments are driven by their future study plans. With only 5% of students putting research as their career priority, this raises concerns about how we educate our physiology students. Should we be educating them to be researchers and also developing their skills in preparation for graduate health-related programs? https://doi10.21692/haps.2019.010

Introduction
Annual increases in Bachelor of Science students undertaking a physiology major
At our large, research-intensive university in Australia, we have seen substantial increases in the number of students selecting to study physiology as part of their Bachelor of Science (BSc) degree-program. Enrolments in the foundational physiology subject/course have increased from 150 in 2011 to 663 in 2018, without similar increases in student enrolments in the BSc degree-program (data extracted from the Monash University Callista Student Management System). Increased physiology undergraduate enrolments have been experienced at other Australian universities (personal communications from participants of the 2018 meeting of the Australian Physiological Society Education Interest Group), as well as in the US higher education system (personal communications from participants of the 2018 meeting of the American Physiological Society Physiology Majors Interest Group). Increased physiology undergraduate enrolments have been experienced at other Australian universities (personal communications from participants of the 2018 meeting of the Australian Physiological Society Education Interest Group), as well as in the US higher education system (personal communications from participants of the 2018 meeting of the American Physiological Society Physiology Majors Interest Group).

It is likely that the entry requirements for Australian graduate medical programs have contributed to enhanced physiology enrolments in the undergraduate science degree program at our university. Of the 19 medical schools that existed in Australia in 2019, nine are undergraduate and eleven are graduate programs. Monash University is counted twice since this university has both graduate and undergraduate medical programs (Australian Medical Association, AMA). In 2000, there were only 11 Australian medical schools, all with undergraduate medical programs that predominantly selected students directly from secondary school (AMA). Most of the current graduate medical programs have physiology as a prerequisite subject in undergraduate degree programs. Similarly, since 2000 many of the Australian university undergraduate degrees have become graduate programs e.g. physiotherapy, paramedicine, nursing, teaching, dietetics, radiography, dentistry, optometry, veterinary science) that often have a physiology prerequisite. Thus, we would expect many of the BSc students majoring in physiology to be aiming for a graduate program in medicine or allied health. This introduction of graduate programs at Australian universities aligns with the US graduate model of higher education (Mercer et al. 2015; Mowery 2015).

Are the increased science student enrolments in physiology facilitated by the students’ career destinations?
It is likely that increased student enrolments in physiology are being facilitated by students’ aspirations for further study and employment/career outcomes. However, it is difficult to find evidence-based data about graduate and career outcomes for 21st century physiology graduates. The UK’s biggest graduate careers website (UK Higher Education Careers Services Unit), quotes 2017 physiology graduate destination data from the UK Higher Education Statistics Agency, with 55% of physiology graduates going into employment (28% into the health area, 13% into childcare/education and 12% as science professionals) and 29% into further study.

University College Cork (Ireland) have been tracking their BSc physiology graduate outcomes. In 2011, 52% of their graduates were in employment and 41% were in further study e.g. graduate medicine, physiotherapy, education,
masters in biomedical sciences, PhD in science research, Masters in Cardiac Rehabilitation and Prevention (University College Cork). Similarly, King’s College London (UK) analysed their physiology graduate destinations from 2012-2014, with 12% in employment and 88% in further study e.g. Dentistry, Medicine, Masters or PhD Science Research, Human and Physiological Sciences Research, and Masters in Global Health and Social Justice (King’s College). An article in The Guardian (UK 2011) quoted a survey of 2009 physiology and anatomy graduates, for which over half went into physiotherapy-related occupations. Other popular career destinations included exercise physiology, pharmaceutical or biotechnology industries (particularly as clinical research associates), laboratory-based research scientists, secondary teaching, scientific writing/journalism, and medical sales. Seventeen percent of the students surveyed went onto further university study, mainly in medicine, dentistry, or a PhD program to become research scientists (The Guardian 2011).

Information about potential career pathways for physiology graduates is provided by the American Physiological Society (APS). They list: researcher (with/without PhD), teacher, public service/government worker, entrepreneur, industry, management and science writer (APS). The University of Cambridge (UK) lists careers for physiology graduates as research (with a PhD), research in the private sector or working for a company, using transferable skills (University of Cambridge).

Information from the University of Manchester (UK), BSc Medical Physiology website indicates that physiology graduates end up with careers in research (at universities, pharmaceutical and bioscience companies or institutes) or in “laboratory-based careers in clinical or technical roles that do not involve research” (University of Manchester). The University of Iowa (US) highlights that careers in health and human physiology include athletic training, exercise science, health promotion, physicians/surgeons, physical therapists, physician assistants, dentists, optometrists, podiatrists, or similar professionals, recreation and sports management and graduate degrees (Masters and/or PhD) in the biomedical or physiological sciences to prepare for careers in research and/or college teaching (University of Iowa).

At our university, we publicise careers for physiology graduates based on the graduate outcomes we have observed. These include: agricultural researcher, audiologist, biotechnology industry worker, Chinese medicine, dietician/nutritionist, echocardiographer, epidemiology, food industry specialist, food technologist, forensic scientist, health economics specialist, health informatics, health promotion researcher, health services worker, information technologist, human resources officer for government or industry, insurance industry researcher, laboratory technologist (health, research or industry), medicine via graduate entry, medical researcher, medical supplies/equipment sales representative, nursing, occupational health and safety, occupational therapy, paramedic, pathology technician, pharmaceutical sales representative, public health worker, policy adviser (to government or industry), reproduction technologist, research scientist, sleep scientist, teacher (secondary/college), toxicologist, veterinary science (Monash University 2000). In summary, it is likely that science/physiology graduates move into a diverse range of careers post-graduation. This is not surprising, as the undergraduate science degree is considered non-vocational, with many students completing the degree because they are interested in science, but do not know what career they would like to follow (Harris 2007; Skatova and Ferguson 2014).

Our hypothesis was that physiology enrolments in our BSc degree program were rising due to physiology requirements for further graduate study programs. We thus surveyed undergraduate science (physiology major) students about their career priorities, their career development and their rationale for their career priorities. The results could have implications for the core concepts and skills development covered in a BSc physiology major. For example, should we be educating and training our physiology students as graduates for a research and/or a health-related career?

**Methods**

*Participants and context*

Participants in this research study were undergraduate students at a large, research intensive Australian university. They were BSc students enrolled in the foundation core second year (BSc) physiology subject (PHY2011: Neuroscience of communication, sensory and control systems) in 2016 and 2017 and a final/third year physiology subject (PHY3072: Muscle and exercise). The numbers of students enrolled in these subjects are provided in Table 1. The PHY2011 course is taught in semester one of year two, and the PHY3072 course is taught in semester two of year three, the final semester of the three-year BSc degree program. It should be noted that at our university, physiology is not taught in the first year of the BSc program. In first year of the BSc program, students take general science subjects such as chemistry, math and physics.

**Table 1. Participants in the research study (PHY2011 = Neuroscience of communication, sensory and control systems subject and PHY3072 = Muscle and Exercise subject)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Subject (number of students)</th>
<th>Subject (number of students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>PHY2011 (558)</td>
<td>not applicable</td>
</tr>
<tr>
<td>2017</td>
<td>PHY2011 (633)</td>
<td>PHY3072 (282)</td>
</tr>
<tr>
<td>2018</td>
<td>not applicable</td>
<td>PHY3072 (244)</td>
</tr>
</tbody>
</table>

continued on next page
**Research design**

At the end of a tutorial, which is an active teaching session led by a faculty member/academic that is held in a flat-floor classroom, with between 60 and 150 students, students were given an overview of the research project and handed a hard copy of an anonymous and voluntary survey. This survey was administered by a person independent of the research study. None of the tutorial classes were compulsory. The survey asked students to:

1. Select their top career priority upon completion of their current degree.
2. Rate their career development and career confidence using four career statements with a seven-point Likert scale from strongly disagree to strongly agree.
3. Provide a written explanation of the rationale for their career intention.

The four careers statements were:

1. I am certain of what career path I want to pursue when I graduate.
2. I know how to develop experience and skills in preparation for my career.
3. I am confident of my ability to communicate my current skills, knowledge and abilities to potential employers.
4. I am confident of my ability to independently manage my career development.

Students were provided with the following options for their top career priorities:

1. To get a full-time job after they finish their degree (specify the area.)
2. Attaining a place in a science honours year.
3. Attaining a place in a science honours year, followed by a PhD.
4. Attaining a place in a graduate medicine course.
5. Attaining a place in a graduate allied health course (specify which area).
6. Attaining a place in a graduate course in teaching (circle primary or secondary.)
7. Attaining a place in another graduate course (specify the course.)
8. Attaining a place in another undergraduate course (specify the course.)
9. I am uncertain or undecided about this; other (please specify).

The survey was administered in the middle of semester one for PHY2011 and at the end of semester two for PHY3072. For most of the PHY3072 students this was the final semester of their degree program.

**Statistical tests and thematic analysis**

Data were collated on an excel spreadsheet and statistically analysed using GraphPadPrism version 7.01. A non-parametric one-way ANOVA (Kruskal-Wallis) was performed across the different student cohorts for each of the career development questions, with a post-hoc Mann-Whitney U test. The written student comments were collated for: (1) the specific graduate allied health program and (2) the rationale for their top career priority. An inductive thematic analysis was used, with coding to identify the main themes in the written comments (Terry et al. 2017). Two researchers independently coding the main themes and their frequency. This research was approved by the Monash University Human Research Ethics Committee and informed consent was obtained from all participants according to ethics protocol number 7195.

**Results**

All of the surveys had high response rates, with an average response rate of 58% across all four surveys (Table 2). The PHY3072 (2018) survey response rate was lower than the other surveys because the tutorial was a revision tutorial and therefore fewer students attended the tutorial.

**Table 2. Student response rates for the surveys (PHY2011 = Neuroscience of communication, sensory and control systems subject and PHY3072 = Muscle and Exercise subject)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Subject (survey response rate)</th>
<th>Subject (survey response rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>PHY2011 (65%)</td>
<td>not applicable</td>
</tr>
<tr>
<td>2017</td>
<td>PHY2011 (55%)</td>
<td>PHY3072 (71%)</td>
</tr>
<tr>
<td>2018</td>
<td>not applicable</td>
<td>PHY3072 (41%)</td>
</tr>
</tbody>
</table>

**Students main career priorities were graduate medicine, or they were uncertain about their future career**

Students were asked what their top career priority was after they graduated from their current BSc degree. Figure 1 shows that an average of 25% of students across all four subjects were undecided or uncertain about their careers, even in their final subject; PHY3072, with 22% indicating that they intended to study graduate medicine, 15% selecting that they would get a full-time job, 10% indicating that they would continue into further graduate study in allied health, 10% selecting honours and only 5% selecting a PhD in science research and 3% selecting teaching. In the Australian and UK university systems BSc students can take a fourth honours year on top of the three-year degree program. This is a research-based year that culminates in the submission of an honours thesis. Students need this honours year to be eligible to undertake a PhD.
Why Do Science Students Study Physiology? Career Priorities of 21st Century Physiology Undergraduates

Many students were uncertain or undecided about their top career priority. A quarter of the students selected indicated that they were uncertain or undecided about their top career priority. The final year PHY3072 (2017) cohort was less uncertain/undecided about their career priorities (17%) compared with the PHY2011 (2016) cohort, which was 26% (Figure 1). This could signify that as the students progressed through their degree from their foundational second year physiology/PHY2011 course to their final semester PHY3072 course, they were more certain about their future career. However, this trend was not observed for the PHY3072 (2018) students compared with the PHY2011 (2017) students.

Of the students who were uncertain or undecided about their top career priority, most stated that they were interested in a few career options but could not, at the time of the survey, pinpoint which option they will take (Table 3). This was followed by a number of students who were uncertain/undecided which career they wanted to do in the future due to the large number of options presented to them. There were a few who wanted to pursue further studies but were unsure which area of study or field to choose. Some were uncertain of the direction of their course or were not sure of their current career options. There were also concerns about their current qualifications to land a job with their degree and whether further studies would alleviate this concern. Students also did not want to worry about their choices until more opportunities presented themselves. Here are some selected PHY2011 student comments that support their main reasons for uncertainty or indecision:

I’m tossing up between a few options. At the moment, I am interested in completing science and potentially doing honours in DEV [anatomy/developmental biology] or PHYSIO [physiology]. I am also considering doing a Master in Teaching. I would also like to get a full-time job. (isn’t that everyone’s goal?)

I think doing an honours year or postgraduate degree in pharmacy, physiotherapy or radiography would be really interesting, however I am still considering medicine, teaching or even honours.

Still unsure about career pathways I will take, undergrad science has opened up [an] overwhelming amount of opportunities.

I am unsure of what my qualifications will be and what jobs I can apply for.

I am currently unsure about what career I want to go in, so thought a broad course like science would be a good way to test the water and see what I like.

I am unsure between finding a job after graduation, and further study. Further study may increase employability but it also may not.

I am not sure whether I will be able to attain a full-time job - more study may be required. Considering many career options.

I am uncertain as to whether after the degree I would try to further my education or to get a full-time job using the degree alone. However, I do take an interest in science and the research that goes into it.

Depends on my grades.
Table 3. Reasons students provided as to why they were uncertain or undecided about their top career priority.

<table>
<thead>
<tr>
<th>Reasons provided for their uncertainty</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Had a few career options but cannot select one</td>
<td>16</td>
</tr>
<tr>
<td>Unsure of career pathway</td>
<td>11</td>
</tr>
<tr>
<td>Not sure of options</td>
<td>6</td>
</tr>
<tr>
<td>Unsure which field or area of study</td>
<td>5</td>
</tr>
<tr>
<td>Uncertain of direction of course</td>
<td>5</td>
</tr>
<tr>
<td>Grade dependence</td>
<td>4</td>
</tr>
<tr>
<td>Unsure of qualifications</td>
<td>4</td>
</tr>
<tr>
<td>Waiting for more opportunities</td>
<td>3</td>
</tr>
<tr>
<td>Aims for honours degree for more options</td>
<td>1</td>
</tr>
<tr>
<td>Doesn’t want to be worried</td>
<td>1</td>
</tr>
</tbody>
</table>

Attaining a place in graduate medicine as the top career priority
An average of 22% of the survey respondents selected graduate medicine as their top career priority. As shown in figure 1, fewer final year PHY3072 (2017) students (15%) wanted to attain a place in a medical program compared with the second year PHY2011 (2016) students (23%). A possible explanation for this could be that by their third year these students have realised that their grades will not get them an interview for graduate medicine, so they selected another choice instead, possibly a full-time job or a graduate allied health program, since there are increases in these career priorities between PHY2011 (2016) and PHY3072 (2017). This trend was not observed between the PHY2011 (2017) and the PHY3072 (2018) cohorts. The written rationales for students selecting graduate medicine as their top career priority were thematically analysed. The most common reasons for students selecting graduate medicine were that they were interested in or passionate about medicine, or that they thought this profession had good career prospects (Table 4). Here are some of the written statements from PHY2011 students:

*Medicine is important to society and I want to contribute.*

*I have a desire to demystify what goes on within the human body when it is confronted with disease, and to identify ways of treating those conditions.*

*I have an interest in helping people, and a career in medicine allows me to combine that desire with a passion for physiology.*

*Doctor: high pay, well respected, get to help people, improve lives, make a difference.*

*I have always wanted to become a GP to treat patients in underprivileged rural communities as I am from a semi-rural background.*

I want to be able to fix people who are sick and feel that nursing does not have the responsibility, pharmacy is too retail and physio isn’t medical enough.

Because medicine is my end goal hence I chose physiology as a subject.

Table 4. Main themes for ‘Explain why you have selected this as your top career priority’ for students who selected graduate medicine (% of student responses for each theme, with highly ranked themes shaded in gray). There were not enough written responses on this topic for PHY3072 in 2018. (PHY2011 = Neuroscience of communication, sensory and control systems subject and PHY3072 = Muscle and Exercise subject).

<table>
<thead>
<tr>
<th></th>
<th>PHY2011 2016</th>
<th>PHY2011 2017</th>
<th>PHY3072 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academia</td>
<td>2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiology a pathway into medicine</td>
<td>2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Career prospects</td>
<td>23%</td>
<td>9%</td>
<td>9%</td>
</tr>
<tr>
<td>Interest</td>
<td>17%</td>
<td>19%</td>
<td>17%</td>
</tr>
<tr>
<td>Job</td>
<td>5%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Money/security</td>
<td>2%</td>
<td>11%</td>
<td>4%</td>
</tr>
<tr>
<td>Passion</td>
<td>20%</td>
<td>37%</td>
<td>52%</td>
</tr>
<tr>
<td>Self-education/ fulfilment</td>
<td>7%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Societal contribution</td>
<td>15%</td>
<td>14%</td>
<td>13%</td>
</tr>
<tr>
<td>Unsure</td>
<td>8%</td>
<td>2%</td>
<td></td>
</tr>
</tbody>
</table>

Getting a full-time job as the top career priority
Fifteen percent of students selected a full-time job as their top career priority. Slightly more students taking PHY3072 in 2018 selected a full-time job (14%) compared with the PHY2011 (2017) students (11%) (Figure 1). This trend was not observed for the PHY2011 (2016) and PHY3072 (2017) cohorts. Full-time jobs reported by the students included analytical chemistry, data research, soldier, journalist, editor, commerce/economics, lab technician, and biotech investor. The student rationales for selecting a full-time job were mainly financial, as illustrated by these PHY3072 student comments:

*I need to pay off my HECS debt [Higher Education Contribution Scheme = university fees].*

*I have done 6 years of study and will be wanting $$$. I need to earn a living.*
Attaining a place in a graduate allied health program as the top career priority

A tenth of the students selected a graduate allied health program as their career priority. This increased as they progressed through their degree, with 8% of the 2016 PHY2011 cohort and 15% of the 2017 PHY3072 cohort selecting graduate allied health (Figure 1). This trend was, however, not observed between the 2017 PHY2011 and 2018 PHY3072 cohorts. Students who selected graduate studies in allied health were asked to specify (with a free text option) which areas of allied health they intended to pursue and the following were provided: audiology, biotechnology, dentistry, dietetics/nutrition/food science, embryology/reproductive sciences/IVF, epidemiology/public health, health management, genetic counselling, nursing/midwifery, occupational therapy, optometry, paramedicine, pharmacy/pharmaceutical sciences, physiotherapy, prosthetics, psychology, radiography, speech pathology, sports science/exercise physiology, and veterinary sciences. The main reasons students provided for selecting graduate allied health programs were because they were interested/passionate about this area or because they wanted to work in the clinical environment. Many students mentioned that physiology was a prerequisite for the allied health graduate program. Here are some selected student comments:

PHY2011 student: I have an interest in helping people, and a career in medicine/any allied health field allows me to combine that desire with a passion for physiology.

PHY2011 student: Because I have an interest in health sciences and helping people. It fascinates me to learn functions of the body and how they interact with each other.

PHY2011 student: To fulfill my goal of becoming a neurologist. I really want to work in a hospital and help people overcome difficulties related to brain development.

PHY2011 student: Paramedicine: physiology is important for my career.

PHY3072 student: I want to work in a hospital, and actually enjoy learning about the physiology of the human body especially the cardiovascular system.

Attaining a place in a science honours (research) year as the top career priority

Ten percent of students selected an honours year as their top career priority, with more year three students (PHY3072) selecting an honours year in 2017: 10%; in 2018: 16%) than the year two (PHY2011) students in 2016: 6%; in 2017: 8%; (Figure 1). Student comments indicated that they were predominantly interested in honours as a pathway into graduate medicine, and did not get an offer for graduate medicine in their final/third year. An honours year increases a student’s grade point average (GPA) and consequently their ranking for selection into graduate medicine is higher. Some students also felt that an honours year would improve their employability. PHY3072 student comments about this:

I am doing honours to increase my WAM [weighted average mean]/GPA for grad med.

The honours year will provide a pathway to achieving a place in graduate medicine.

Because it seems impossible to get a job without honours also not sure yet what career path I want.

So that I have a greater qualification for future job prospects (honours).

Few physiology students selected a PhD as their top career priority

Only 5% of the students selected an honours year and PhD in science research as their top career priority. In Australia, you cannot undertake a PhD without an honours year. Most of these students intended to pursue a career in research, as illustrated by these selected written comments:

PHY2011 student: I am interested in research as I am a person who constantly questions the world around and why things are like they are.

PHY2011 student: I believe it suits my strengths and will be an interesting and engaging career.

PHY2011 student: I would like to research neuromuscular cell contraction pathways for sports science and cardiac physiology.

PHY2011 student: I want to go into the field of marine biology research, specifically animal ecophysiology.

PHY2011 student: This is an area of study [physiology] that I have been greatly interested in. Working in this area will be both knowledgeable and fascinating.

PHY2011 student: I like studying and would like to be an expert in my field. Afterwards, I would like to use my physiology knowledge in the workplace.

PHY3072 student: I would like to pursue a career as a researcher where I can make a difference.

Few students selected attaining a place in a graduate teaching program (primary or secondary) as their top career priority

An average of only 3% of the students selected teaching as their top career priority (Figure 1). Their reasons for selecting teaching included that they enjoyed working with children and that they wanted to help their pupils to succeed with their learning. This is illustrated by the student comments below.

PHY2011 student: Love to teach others and see them succeed.
PHY2011 student: I work casually/regularly at a school in various departments including the school’s boarding house. I really enjoy working with kids and think a career in teaching would be very rewarding.

PHY2011 student: I wish to work in education and want to be able to do this in the scientific field.

PHY3072 student: Always been interested in teaching; would be an interesting career choice.

Careers confidence and careers awareness of physiology students
The students’ ratings for the four career development statements significantly increased from year two (PHY2011) to year three (PHY3072) for statements 2 (I know how to develop experience and skills in preparation for my career), 3 (I am confident of my ability to communicate my current skills, knowledge and abilities to potential employers) and 4 (I am confident of my ability to independently manage my career development), but not for statement 1 (I am certain of what career path I want to pursue when I graduate) - Figure 2 and Table 5. Despite being near the end of their degree program, PHY3072 students were no more certain of their career paths than the PHY2011 students at the start of the second year of their degree program.

Figure 2. Student responses to four career development statements (7-point Likert scale from strongly disagree to strongly agree) Data are expressed as the median (black line in box) and the 25 and 75 percentiles. The maximum and minimum have not been plotted as they were always 7 and 1, respectively, for all cohorts (PHY2011 = Neuroscience of communication, sensory and control systems subject and PHY3072 = Muscle and Exercise subject).
Why Do Science Students Study Physiology? Career Priorities of 21st Century Physiology Undergraduates

Discussion
The most commonly selected career priority was that the student was uncertain or undecided about their future career, followed by graduate medicine and getting a full-time job. This is consistent with our hypothesis that increasing physiology enrolments in the BSc are being driven by the physiology prerequisites for graduate medicine. The uncertainty about their future career direction, as ascertained by students’ career priorities (or lack thereof) and their career confidence, suggests that career development needs to be embedded into the physiology major of the BSc degree program.

The Bachelor of Science is a non-vocational degree program with diverse career outcomes
The Australian BSc degree program is considered non-vocational, with a diverse range of career outcomes. Many students choose to study science because they do not know which career they want to pursue and they are interested in science (Harris 2007; Skatova and Ferguson 2014). Indeed, we found that about a quarter of Monash BSc physiology major students indicated that they were undecided or uncertain about their career, even near the end of their final physiology subject (PHY3072 (Figure 1). At this time point most students would have been notified if they were successful at obtaining a place in a graduate degree program. This uncertainty about their future career is reflected in their responses to the first career development statement ‘I am certain of what career path I want to pursue when I graduate from science’ with no consistent change in the rating for this statement between year 2 (PHY2011 foundational physiology subject) and year 3 (PHY3072 final year physiology subject).

A need for undergraduate career development
Given the degree of student uncertainty and indecision about their career, it is clear that we need to educate BSc physiology major students about their career options. This idea is supported by the PY2011 student comment that “undergrad science has opened up [an] overwhelming amount of opportunities”; the non-vocational aspect of the BSc, with diverse career outcomes, could make it difficult for students to develop specific career goals. Career development and improving their employability is a key focus for many students entering higher education (Kandiko and Mawer 2013). This is especially important for a non-vocational undergraduate degree program, such as the BSc, that has no fixed, single career outcome.

Career development learning, including self-awareness, occupational exploration, decision-making and career management, is considered to be a key component of graduate employability (Watts 2006; Dacre Pool and Sewell 2007). Meta-analyses of the careers outcome literature indicates that assisting students to explore possible future careers promotes their employability and well-being (Brown and Roche 2016; Watts and Hawthorn 1992; Whiston, Sexton and Lasoff 1998). However, educating BSc physiology major students about their career options is hindered by our lack of quantitative knowledge about the graduate/career outcomes of our physiology graduates, so we cannot tell current students what the actual career outcomes for physiology graduates are.

We have been running a career development and employability workshop in the PHY2011 subject since 2016. This seems to be having an impact, as the PHY3072 (final year) students were significantly more confident than the...
PHY2011 students about their career development (Figure 2), with higher ratings for 'I know how to develop experience and skills in preparation for my career', 'I am confident of my ability to communicate my current skills, knowledge and abilities to potential employers' and 'I am confident of my ability to independently manage my career development'. It should be noted that the PHY2011 students completed this survey before their careers/employability workshop and all of the PHY3072 students had completed the workshop in PHY2011.

Many students are taking physiology subjects because they are prerequisites for graduate programs in medicine and allied health areas
Throughout all of the cohorts, a third of students (32%) selected graduate medicine (average of 22% across all cohorts) or graduate allied health programs (average of 10% across all cohorts) as their top career priority. Graduate medicine and most allied health programs require undergraduate physiology as a prerequisite subject. Therefore, these data are consistent with our hypothesis that the increased numbers of students selecting physiology in the BSc is being facilitated by their career intentions.

Currently, we educate our BSc students to be scientific (physiology) researchers. However, according to our data very few (5% on average across all cohorts) of these students progress into a research career, while a third plan to move into health-related studies and careers. This raises concerns regarding how we are educating our physiology students. Should we instead be educating them to be researchers and also preparing them for graduate health-related programs? One Australian university appears to be following this idea and has rebranded a science degree as a Bachelor of Pre-Medicine Science and Health (Biomedical Research). This degree is marketed as a "3-year degree that provides a solid foundation for those students aspiring to undertake postgraduate study or professional practice in medicine or other health or science related fields" (University of Wollongong). This degree program covers the biomedical science disciplines, research and the scientific process and also subjects like 'Cultural Competence in Health Care Practice' that prepares students for study and work in health-related areas. Similarly, a Biomedical Science undergraduate major was recently created at The Ohio State University for students interested in scientific research and health-related professions. The curriculum includes basic science and clinical research experience, skills development related to work as a healthcare professional (teamwork, problem solving and communication) and a clinical internship (see Gunn et al. 2018).

In the capstone subject of the biomedical major of the BSc at the University of Queensland, they have developed authentic assessments that reflect their students' intended career pathways. Students are required to select one of three assessment streams: Scientific research; Clinical professions (for students pursuing further study in medicine and allied health) or Biomedical industry. They found that about two thirds of students in 2018 selected the clinical stream (Young et al. 2018). This indicates that (like physiology students) the majority of biomedical students are aiming for graduate medicine or other allied health areas. These examples show how a curriculum could be modified such that it aligns with the physiology graduate career outcomes.

With about a third of our science/physiology students at Monash University aspiring to attain a place in a graduate medical or allied health program, a process which is dependent on their academic performance in their undergraduate subjects, it is likely that this will impact on student behaviour and expectations. At our university, we have found that more students are asking for remarking of assessments or querying their exam grades. There are also more students putting in for special considerations and deferral of assessment due dates. There is also evidence that levels of undergraduate science and biomedical anxiety are increasing (Larcombe et al. 2016). Student focus groups have indicated that this anxiety is associated with the competition for the high grades that will enable students to attain a place in a graduate medical program (personal communication, J. Choate). In order to address unprofessional behaviour in our biomedical science cohort, this year we introduced a compulsory professionalism practice code of conduct for the biomedical students.

Limitations and future directions
There are a number of minor limitations with the survey design and administration:

(1) Given that many students selected more than one career priority when they completed the survey, and were thus excluded from the analysis, it would be better to allow students to pick more than one career priority, or to rank them, or indicate their level of confidence for each career option.

(2) A part-time job/employment should also be on the careers list since in the modern workforce, many young people juggle multiple part-time jobs.

(3) It would have been better if we had tracked career priorities of our BSc physiology students in alignment with the increased enrolments from 2011 to 2018, not just from 2016 to 2017.

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(4) There was a lower response rate for the PHY3072 2018 survey. Of the PHY3072 2018 cohort, only 41% of students completed the survey compared to 71% from PHY3072 2017. This was probably due to the nature of the tutorial in which this survey was administered, as it was a revision tutorial, rather than a standard tutorial. This low response rate may have affected the trends observed, when compared to the higher response rate for the cohort of PHY2011 in 2017.

In the future, there is a critical need for tracking of BSc physiology major students graduate destinations, but it is currently unclear how this can be effectively achieved, especially given the large student enrollments in physiology. As physiology educators, we should also aim to embed career and employability skills development into the physiology curriculum.

Acknowledgements
We would like to thank the students who took the time to participate in this education research project. In addition, we would like to thank Simone Carron (PHY2011) and Joanne Caldwell (PHY3072) for administering the surveys and Kushani Weerakoon and Xiaochu Cai for collating the information from the hard copy surveys into Excel.

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An Innovative Method of Instructing Relational and Sectional Anatomy in The Classroom Using an Audience Response System

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Abstract
Classroom instruction of relational and sectional anatomy presents unique teaching challenges associated with cultivating student proficiency in abstract visualization of two-dimensional representations of three-dimensional anatomical structures. Current audience response systems (ARS) are well understood to effectively engage large classes and promote student participation, allowing students to participate in class activities using their personal handheld devices. The use of an ARS in the instruction of relational and sectional anatomy was piloted in two cohorts of the Medical Radiography program at the British Columbia Institute of Technology, Burnaby, British Columbia, Canada. At term-end, students were invited to submit responses to a questionnaire. Feedback was overwhelmingly positive for the use of an ARS in the classroom; students indicated that the ARS image-based structure identification question type was particularly useful for their learning of relational and sectional anatomy. https://doi.org/10.21692/haps.2019.013

Key words: sectional anatomy; audience response; teaching

Introduction
Relational and sectional anatomy is a core subject of medical diagnostic imaging technology programs that is taught in conjunction with standard human anatomy and clinically relevant physiology. This sub-discipline of the traditional study of anatomy focuses on how anatomical structures are located in relation to each other and also how they appear in two-dimensional (2D) representations of the human body, including cadaveric slices, computed tomography (CT) scans, magnetic resonance imaging (MRI) scans.

For the anatomy educator, the main challenge accompanying the instruction of relational and sectional anatomy is finding creative ways to cultivate skill sets involving image-based identification of anatomical structures and abstract visualization within the limitations of the average college classroom learning environment. Medical diagnostic technology programs that require relational and sectional anatomy are usually offered by smaller college academic institutions with a paucity of anatomical resources (e.g. cadaveric specimens and dissection laboratories, anatomical models) that would normally be used to complement the study of relational and sectional anatomy. In addition, the compressed timeline of these densely scheduled technology programs confines anatomy and physiology courses to a large group lecture environment, with relational and sectional anatomy content interspersed with standard anatomy and physiology content. In the context of relational and sectional anatomy, teaching and learning resources that can effectively engage students, accommodate the delivery of necessary image-heavy content, and strategically avoid the onset of student boredom and indifference, are always much desired.

The audience response system (ARS) has been well reviewed and extensively assessed as an effective teaching and learning tool for promoting greater interaction and student feedback within the lecture environment (Fies and Marshall 2006; Caldwell 2007; Kay; Stowell and Nelson 2007; LeSage 2009). ARS platforms have been used in the teaching of anatomy and physiology (Alexander 2009; Hoyt et al. 2010; Wait et al. 2009; Halliday et al. 2014). Since their inception, ARS platforms have undergone an evolution from traditional plastic clickers (e.g. i-Clicker®) to Powerpoint®-based polling systems (e.g. TurningPoint® – Turning Technologies/Responseware) to rudimentary web-based polling systems (e.g. Kahoot®, Poll Everywhere®) accessed using student personal devices with observed favourable student responses (Koppen 2013; Stowell 2015). While this array of ARS platforms provide individual strengths and benefits, cumbersome interfaces, glitchy software, limited interactive features, and the requirement of students to purchase devices with no other function beyond polling purposes, are detractions.

The most current ARS platforms enlist the use of personal devices (e.g. smartphones, tablets, laptops), permitting student participation in class using downloadable applications (“apps”) or by accessing content through the ARS website. Since the overwhelming majority of students possess smartphones and other wifi-enabled devices and are comfortable with downloading and using apps, the logical extension is to repurpose the prevalent student use of personal device technology for constructive teaching and learning purposes.
An Innovative Method of Instructing Relational and Sectional Anatomy in The Classroom Using an Audience Response System

One particular ARS feature that is promising for the instruction of relational and sectional anatomy, with different names across different ARS platforms, is the image-based structure identification question type. This feature allows the instructor to upload and project an image in the classroom; this image simultaneously becomes visible on the personal devices of the students through the ARS app or website. Students can select regions of the image in alignment with the instructor’s request for identification of specific regions. The ARS collects the data from all participating students and creates a graphic, superimposed on the image, that summarizes the regions of the image selected by the students.

This study assesses the use of an ARS in the instruction of relational and sectional anatomy in two separate cohorts of the BCIT Medical Radiography program, seeking to demonstrate its effectiveness in engaging students and cultivating specific diagnostic imaging analysis skill sets that are traditionally difficult to nurture and develop in a college-based classroom.

Methods
Following a broad assessment of several ARS platforms and the interactive features that they offer, the ARS TOP HAT™ was selected for this study. TOP HAT™ was evaluated in the relational and sectional anatomy and physiology courses of two separate student cohorts of the Medical Radiography program at BCIT, one cohort in the Fall 2017 semester (course BHSC 2214, n=79) and the other cohort in the Winter 2018 semester (course BHSC 4214, n=72). Complimentary one-term student subscriptions were provided by TOP HAT™ Monocle Corp. All participating students signed consent forms at the beginning of their respective semesters.

Prior to the conclusion of their respective trial periods, both cohorts of students were provided, by e-mail invitation, a voluntary option to participate in identical online questionnaires that evaluated the use of TOP HAT™ in the classroom and its use in the study of relational and sectional anatomy and physiology. As recommended by the BCIT Research Ethics Board, only the e-mail invitation to the survey and several brief reminders in class regarding the survey were provided; no class time was given for this survey to minimize potential bias of instructor-mediated coercion of students for feedback. Respondents were given the option to skip any of the questions in the questionnaire. These questions were approved by the BCIT Research Ethics Board and administered in accordance with the Institute’s Research Ethics for Human Participant Policy #6500, which itself is derived from the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2).

Results
There were 50 respondents to the online questionnaire, 32 students from the Fall 2017 semester and 18 students from the Winter 2018 semester (in total, a 33% response rate). In the classroom, 85.7% of respondents used their smartphones to access TOP HAT™, 10.2% used their laptops, 4.1% used their tablets. TOP HAT™ features were accessed via the TOP HAT™ app by 83.7% of respondents and the TOP HAT™ website by 16.3% of respondents.

Respondents were asked how TOP HAT™ impacted their in-class learning and their participation in class discussions and interactive learning activities. 81.3% of respondents noted that TOP HAT™ positively impacted their in-class learning and 18.8% of respondents noted that TOP HAT™ somewhat positively impacted their in-class learning (Figure 1).

![Figure 1. Questionnaire responses inquiring how students felt TOP HAT™ impacted their in-class learning. N=48.](image)

With regard to how TOP HAT™ impacted their participation in class discussions and interactive learning activities, 75.5% responded “strongly encouraged participation” and 24.5% responded “encouraged participation” (Figure 2).
Figure 2. Questionnaire responses inquiring how students felt TOP HATTM impacted their participation in class discussions and interactive learning activities. N=49.

Respondents were provided with a list of learning opportunities facilitated by TOP HATTM and asked which ones they felt were the most helpful; 96% of respondents felt TOP HATTM provided an in-class review of previously presented course content, 62% of respondents felt TOP HATTM provided an assessment of existing student knowledge prior to presenting course content, 44% of respondents felt TOP HATTM provided out-of-class review of course content, 66% of respondents felt TOP HATTM promoted student engagement and participation, and 40% of respondents felt TOP HATTM promoted in-class discussions (Figure 3).

Figure 3. Questionnaire responses inquiring what learning activities facilitated by TOP HATTM were most helpful for students. N=50.

The most popular TOP HATTM question types among respondents were the Click-on-Target and Multiple Choice question types (90% and 94% of respondents respectively), followed by the Matching question type (38% of respondents), Word Answer/Word Cloud question type (16% of respondents), and lastly Sorting-and-Rank (8% of respondents), Numeric (2% of respondents), and In-class Discussion function (4%) (Figure 4).

Figure 4. Questionnaire responses inquiring what question types offered by TOP HATTM were most useful for in-class learning. N=50.

At the end of the online questionnaire, students were given the opportunity to expound on their feedback and impressions of TOP HATTM use in the classroom; a sampling of the submitted student comments is provided below:

[Top Hat] is a great way to have everyone in class participate/engage more and also a good way to assess your understanding and knowledge about the content being taught in lecture/review.

I enjoyed that it was like being quizzed without the added pressure of taking an exam and was usually followed with explanations and a teaching moment which I found very useful.

I think [Top Hat] was greatly beneficial to my learning as it allowed greater discussion and a place to determine where the professor needed to focus more or explain in greater detail.

[Top Hat] was a great way to present your answer without the worry of speaking out in front of everyone. Also makes you competitive to get it right, like a game. [Top Hat] keeps me focused and entertained.

Discussion

Relational and sectional anatomy knowledge is an essential competency in the program curricula of those training in the fields of diagnostic medical imaging, including Medical Radiography, Nuclear Medicine, Radiation Therapy; it is usually taught in conjunction with standard anatomy and physiology...
content. In addition, other related fields such as Prosthetics and Orthotics, require a thorough understanding of regional relational and sectional anatomy, especially how portions of the human body may be interrupted through amputation. Within these courses containing relational and sectional anatomy content, students devote significant time to developing the necessary skills to identify anatomical structures on images derived from different image modalities, learning how to anticipate and predict how the appearance of anatomical structures will change based on native organ shapes and the presence of pathology.

The delivery of relational and sectional anatomy content in the classroom is traditionally dry, usually relying on the instructor to present a series of projected diagnostic medical images, pointing out various anatomical structures and pathologies. Since these relational and sectional anatomy identification skills are necessarily cultivated through repetition and reinforcement of techniques of, and exercises in mental visualization, it is challenging for the instructor to engage the class as a whole and also ensure the development of individual student skill and proficiency. Furthermore, academic institutions that offer programs in medical diagnostic imaging technologies tend to be smaller, lacking resources (e.g. cadaveric dissection, pathology samples, anatomical museum specimens and models) that would be helpful in the study of relational and sectional anatomy. Thus, methods of improving the delivery of relational and sectional anatomy content must be practically enlisted in the classroom and accessible to a large group of students at one time.

ARS technology has improved significantly from its origins in the use of plastic clicker devices which required remote transponders to collect student responses. Increased student use of computers in the classroom, coupled with the now-common availability of dependable wi-fi in the classroom, enabled the capacity for online polling and eliminated the previous need for plastic clickers and remote transponders. Currently, ARS functionality has embraced app and web-based media, taking advantage of the new normal that the majority of students now carry and use personal technology devices such as cellphones, tablets and laptop computers. The convenience of use, as well as the enhanced interactive functions facilitated by these devices provide a way to further engage students, promote participation and encourage student self-review. It is for this reason that the ARS was selected for evaluation of its ability to enhance the learning of relational and sectional anatomy, a subject traditionally challenging to teach in a classroom environment.

There are many app-based and web-based ARS platforms available for educational use, each with their own selection of traditional, commonly used features (e.g. multiple choice, sorting, matching question types) and unique features. In keeping with the need for interactive features that permit students to collectively evaluate anatomical structures on projected images in the classroom, three ARS platforms were identified, Poll Everywhere™, Learning Catalytics™ and TOP HATTM. Poll EveryWhere™s feature Clickable Image, Learning Catalytics™s Region question and TOP HATTM’s feature Click-on-Target are similar in function, allowing the instructor to simultaneously project an image on the classroom screen, transmit that same image to students on their personal devices, and allow students to select a desired region on the image. When comparing the functionality and visual appearance of the three features, TOP HATTM was the ARS that was enlisted for this study.

In the classroom, the majority of respondents used their smartphones to access ARS content through the downloaded app, affirming the popularity and prevalence of smartphone use, and reinforcing the point that classroom interaction facilitated through smartphones is a convenient way for many students to contribute to in-class discussions and activities. The remaining respondents who used their tablets and laptops are likely those that use these devices predominantly for their classroom learning purposes, switching between apps or window screens as a matter of convenience.

In-Class Learning
In assessing their in-class learning experience, respondents either stated that the use of the ARS positively impacted their in-class learning or somewhat positively impacted their learning. No respondents rated their in-class learning experience as neutral, somewhat negatively impacted nor negatively impacted. These results strongly suggest that students felt their in-class learning experiences benefitted from the use of the ARS.

Respondents noted that the use of the ARS strongly encouraged participation or encouraged participation in class discussions and interactive learning activities. These results suggest that the ease of access to the ARS platform, and its ability to facilitate anonymous (to peers) contribution within the classroom makes it more favourable for students to submit their opinions and perspectives free of the commonly held fear of publicly contributing an incorrect answer.

Within these Medical Radiography courses, different learning opportunities facilitated using the ARS were evaluated. The observed variances in the responses to these listed learning opportunities is likely a consequence of both instructor preference and individual student preference for the use of the ARS in the classroom. For instance, the ARS was primarily used as a means of informal in-class review of previously presented course content, and also as a way to evaluate existing student knowledge prior to presentation of a given topic. Thus, in the feedback, these learning opportunities were noted as more favourable to students, in contrast to those learning opportunities that were used less frequently (e.g. out of class review on the app or website, in-class discussions).

From a different perspective, variances in individual student

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needs, preferences and expectations for the use of a given resource during class time can also influence the learning opportunities that students noted to be most helpful. Students prefer to have consistent reinforcement of their standing in the course, to reaffirm how much they have learned and retained, and what they still need to master; this is likely why in-class review and assessment of existing student knowledge ranked higher, along with promotion of student engagement and participation. As well, even though the ARS content was made available for review outside of class via the app or the website, student may not have preferred to take advantage of this.

Finally, although the ARS features facilitated a means of in-class discussion, often it is difficult to cultivate meaningful discussion amongst students within a large classroom setting; this could be the reason why this particular learning opportunity ranked lower than the others.

Evaluating The Image-Based Structure Identification Feature

The most popular ARS question types among respondents were the image-based structure identification question type and the multiple choice question type. Aside from general student preference for question types, these numbers are also a reflection of the predominant use of certain features over others.

The image-based structure identification question type in TOP HAT™, Click-on-Target, was well received by the Medical Radiography students. To date, this is an innovative, relational/sectional anatomy-specific use of this feature that has not previously been reported. The instructor uploads a jpg image to the platform and selects one or more circular regions, modifiable in size, (initially invisible to students) for identification; this jpg image is projected on the classroom screen and simultaneously appears on all student devices (via the app or website). On their devices, students, by touch, select their desired region or regions of the image, as directed by the instructor. The selected regions from all class participants are collated and summarized in a heat map graphic superimposed onto the original image that is able to be projected onto the screen during lecture for classroom debrief purposes. The heat map enlists several colours that are used to denote the popularity of selected regions; densely selected regions of the image are red, medium-dense selected regions of the image are orange/yellow, and the least dense selected regions of the image are green/blue.

The visual aesthetic of the heat map and how it summarizes the selected regions of the image using a spectrum of superimposed colours was the deciding factor for the selection of the ARS TOP HAT™ for this study. In comparison, Poll Everywhere™’s Clickable Image achieves a similar goal by allowing the instructor to select one or more square/rectangular regions (modifiable in size) on an image for students to select on their devices. However, instead of a heat map, the summarized data is presented as tiny identical coloured pins superimposed on the image. Visually, this feature works well if there are many pins centred around a given region (e.g. the majority of students select the same region). However, if students happen to select multiple differing regions of the image, the dispersed distribution of the pins across the image is not as visually succinct compared to the heat map. The same visual aesthetic issue with a superimposed graphic of coloured pins/dots seen in Poll Everywhere™’s Clickable Image is also encountered with the Region question from Learning Catalytics™.

The relational and sectional anatomy-based modification of the use of the Click-on-Target question type that was enlisted during this pilot study consisted of uploading jpg images of CT and MR images, and selecting for anatomical structures featured on those images. Figure 5 features a sample Click-on-Target question demonstrating in the panel on the left how an instructor selects a region for identification, the body of the pancreas, and on the right, how student responses are summarized as a heat map and projected in-class.

**Figure 5:** An example of a Click-on-Target question, before (left) and after (right) the collation of student responses. On the left, the circular, outlined region is the area that denotes the correct answer. On the right, the colored areas represent the collated student responses reformatted into a heat map based on the frequency of areas selected by the students.
From the instructor perspective, Click-on-Target is a valuable tool for cultivating relational and sectional anatomy skill sets. First, it allows all participating students to contribute a response anonymously, promoting class-wide participation and engagement, compared to the traditional scenario of projecting an image and then asking students to speak up individually. Next, the heat map provides both the instructor and the students a convenient barometer for student comprehension regarding class-wide understanding of the relational and sectional anatomy content; the instructor instantly can recognize if the content is being understood or not, and the student can instantly observe how he/she answered in relation to the rest of the class, providing a necessary and implicit cue that a given topic may or may not require further review. Finally, the heat map creates a unique opportunity for valuable relational and sectional anatomy discussion that is normally difficult to have within the classroom. Using the heat map, the instructor can speak to the reasons why some students may have selected the wrong region, and also provide tips/clues for what to look out for the next time.

For example, in Figure 5, there are two main areas where student identification was concentrated, one being the correct answer (the pancreas), and the other being an incorrect answer (the left splenic flexure). Once students see the final heat map, the instructor can hide it, allowing students to review the raw image permitting them to reflect on the similarities and differences between the two regions previously indicated by the heat map.

Lastly, while TOP HATTM was selected for this study based on its heat map function, it should be noted that out of the three ARS platforms assessed, the Region question from Learning CatalyticsTM is the only one that allows the instructor to designate an irregularly shaped region on the image for selection by students; presently, TOP HATTM’s Click-on-Target permits only circle regions to be selected, and Poll EverywhereTM’s Clickable Image permits only square/rectangular regions to be selected. Since anatomical structures are often irregularly shaped, this particular capability of the Learning CatalyticsTM’s Region question allows it to be another promising option for use in the presentation of relational/sectional anatomy content in the classroom.

The pilot study success encountered with this reported innovative use of an ARS image-based structure identification feature in the classroom highlights the benefits associated with the use of an ARS to engage large classes through the use of individual student personal devices. As well, this study demonstrates how the continually improving interactive capabilities of ARS platforms and personal device technology can be purposed to augment and enhance the study of a traditionally dry subject like relational and sectional anatomy.

Conclusion

ARS technology has improved dramatically since its initial offerings requiring the use of remote transponders and individual plastic clickers; current ARS platforms with their ability to engage students via app or web-based means using student personal devices has revolutionized how course content is presented, reinforced and reviewed and how certain skill sets are cultivated in the classroom setting.

The piloted use of an ARS in two cohorts of the Medical Radiography program at BCIT was a success, with respondents noting that the use of its interactive features had a positive impact on in-class learning and encouraged participation within the classroom. Most importantly, the innovative use of an image-based structure identification question type to optimize the presentation of relational and sectional anatomy content was particularly well received as a unique way to develop and reinforce student relational and sectional anatomy knowledge and proficiency.

Acknowledgments

The ARS TOP HATTM was selected due to its particular version of the image-based structure identification question type. TOP HATTM Monocle Corp. provided complimentary one-term subscriptions for all BCIT Medical Radiography students participating in the pilot study. The author recognizes that this can represent a conflict of interest as there are other existing ARS products and platforms that provide similar question types and features.

The author acknowledges the contribution of and collaboration with Dr. Megan Murphy in the creation of the pilot study questionnaire. The author thanks Dr. Bassam Nyaeme and Dr. Jennifer Kong for reviewing the manuscript, the BCIT Department of Basic Health Sciences and the BCIT Medical Radiography Program faculty and staff for their assistance and support throughout the course of the pilot study.

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Plasticity in the Periaqueductal Gray (PAG) Region of the Brainstem Contributes to Analgesia

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Abstract
Pain is an aversive event created in the body, often in response to potentially dangerous stimuli. However, millions of people experience pathological pain. Pathological pain includes chronic neuropathic pain, which has its origin in the nervous system and is often due to damage or dysfunction of the somatosensory system. Understanding the somatosensory system is one of the major medical challenges of our time. Approximately 16% of Americans experience neuropathic pain. The cause of these pathological events is unknown, but current research indicates plasticity in brain areas, especially the periaqueductal gray (PAG), can modulate the perception of pain. Elucidating the mechanisms of sensitization in this area provides attractive targets for the treatment of pathological pain and the plasticity of the pain circuits provide an excellent pedagogical opportunity for courses in physiology or neuroanatomy. https://doi10.21692/haps.2019.003

Key words: nociception, analgesia, neuroanatomy, periaqueductal gray

Introduction
Nociception is the detection of potentially dangerous stimuli by specialized receptors known as nociceptors (Carlton 2014). Nociceptors are essential for protection and survival. They are sensitive to mechanical, thermal, and chemical stimulation, in the range that is potentially damaging to tissues. The signal connection from the noxious stimuli to the brain enables humans to physiologically shelter and protect their tissues from severe damage (Brooks and Tracey 2005). Activation of nociceptors results in a signal along the primary afferent fiber to the dorsal horn of the spinal cord, which then ascends to the brain (Carlton 2014). Pain perception results from an integration of these signals within cortical areas of the brain. Pain associated with an appropriate mechanical, chemical, or thermal stimulus is called nociceptive pain (Gierthmuhlen and Baron 2016).

Neuropathic pain has its origin in the nervous system, rather than a nociceptive stimulus, and often occurs as an acute pain transitions to chronic pain. The Periaqueductal Gray (PAG), a region in the midbrain surrounding the cerebral aqueduct, has long been known to play a role in pain. Processing and pathological activity in the PAG has been implicated in neuropathic pain. The mechanisms of neuropathic pain are under intense scrutiny in the search for treatments to reduce the heavy economical and public health burden of neuropathic pain. Approved treatments for neuropathic pain include modulators of calcium-channels, tricyclic antidepressants, and serotonin reuptake inhibitors that target inappropriate synaptic function, which results the perception of pain (Fornasari 2017; Gierthmuhlen and Baron 2016). Here, we will review the circuits underlying pain sensation and pain modulation, including the neurotransmitter and neuropeptide systems used at each level, closing with the utility of this system in developing a teaching module prompting students to develop a pain treatment protocol.

PAG, Function and Anatomy
The PAG is essential in integrating diverse signals from throughout the body and modulating the perception of pain (Behbehani 1995). At the interface between the brainstem and forebrain areas, the PAG receives ascending nociceptive signals from the spinal cord and trigeminal nucleus, but also integrates signals from the limbic and forebrain areas (Benarroch 2012; Linnman et al. 2012). Located within the superior portion of the brainstem, the PAG is an elongated oval structure comprised of gray matter and functionally divided into four columns-based afferent inputs, including the dorsomedial, dorsolateral, lateral, and ventrolateral subdivisions (Bandler and Shipley 1994; Carrive 1993). The ventrolateral PAG (vPAG), like several of the other sections, projects to lower areas of the brainstem, and thus plays a role in descending modulation of pain (An et al. 1998). Outputs of the PAG include several other midbrain nuclei, including the locus coeruleus (LC) and rostral ventral medulla (RVM), both of which also project to neurons in the spinal cord transmitting nociceptive information (Behbehani 1995).

Neurons in the PAG
The PAG is composed of both glutamatergic and GABAergic neurons, both playing a crucial role in the intrinsic neuronal circuitry of the PAG and, thus, in the perception and modulation of pain (Benarroch 2012). Generally, glutamatergic neurons are excitatory to downstream targets, while GABAergic neurons inhibit the activation of their targets.

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The functional interplay between these two neurons within the PAG is explained through the disinhibition hypothesis, in which GABAergic neurons exert tonic inhibition on the glutamatergic neurons (Liao et al. 2011). As a result, glutamatergic PAG neurons are indirectly activated through the inhibition of the tonic GABAergic neurons. This glutamate signaling within the PAG then leads to the activation of the excitatory subset of glutamatergic neurons, which causes stimulation of the descending pain modulatory pathway, resulting in an analgesic effect (Benarroch 2012).

Ascending Modulation
Pain processing within the central nervous system can be controlled via ascending pathways. The ascending system is comprised of several different pathways, beginning in the periphery and projecting to supraspinal areas, including the PAG. All of the ascending system is responsible for the transmission and modulation of sensory signals from peripheral receptors to the cerebral cortex. Nociceptor activity is pivotal in receiving and processing sensory stimuli and is the primary component in the cascade of signals that results in the conscious perception of pain. Painful stimulation activates the nociceptors, which then send a primary afferent fiber, either Aδ or C fibers to the dorsal horn of the spinal cord where they synapse with other neurons and ascend to the brain via the spinothalamic tract (Carlton 2014). The spinothalamic tract is comprised of afferent sensory neurons that are responsible for pain and temperature sensation (Carlton 2014). These neurons then project from the thalamus to the primary somatosensory cortex, which arbitrates the sensory discriminative aspects of pain, allowing the intensity, frequency, and location of the noxious stimulation to be perceived. In addition to the thalamic projections, these ascending neurons project to brainstem areas, including the PAG (Ikeda et al. 2006).

Pain perception can be modulated in this ascending pathway through a host of chemical signals that act on the ascending neurons (Carlton 2014). The primary afferents in this system contain µ-opioid receptors that, when activated, decrease the sensitivity of the nociceptors (Zeng et al. 2006). Neuropeptide Y (NPY), which plays a role in an increasingly long list of physiological processes and is released due to a diverse set of stimuli, activates a distinct set of receptors in the dorsal horn to decrease the sensitivity of nociceptive afferent transmission. The interneuron synapse occurring within the dorsal horn inhibits the synaptic transmission between the nociceptive afferent and the second-order neurons in the spinothalamic tract (François et al. 2017). The activation of opioid receptors also causes the reduction of nociceptive afferent transmission. The interneuron synapse occurring within the dorsal horn inhibits the synaptic transmission between the nociceptive afferent and the second-order neurons in the spinothalamic tract (François et al. 2017). The inhibition of these afferents prevents ascending pain information from being projected to the brain (Figure 1).

Figure 1. Neurons of the PAG influence ascending nociceptive pathways. Descending tracts from the PAG synapse within the RVM and nucleus raphe magnus, which control the excitability of the secondary afferents of the nociceptive system.

Descending Modulation
Activation of the PAG pathways decreases the excitability of primary nociceptive neurons, thus requiring a more intense noxious stimulus to activate the sensor. Descending projections from the PAG travel to lower brainstem regions such as the RVM, nucleus raphe magnus, and the LC, which project to the dorsal horn of the spinal cord (Martins and Tavares 2017). Upon stimulation by the PAG, these two descending pathways release serotonin and norepinephrine onto the dorsal horn, which results in the release of the endogenous opioid peptides enkephalin and dynorphin (François et al. 2017). The activation of opioid receptors also causes the reduction of nociceptive afferent transmission. The interneuron synapse occurring within the dorsal horn inhibits the synaptic transmission between the nociceptive afferent and the second-order neurons in the spinothalamic tract (François et al. 2017). The inhibition of these afferents prevents ascending pain information from being projected to the brain (Figure 1).
Plasticity of PAG Neurons Results in Analgesia

Synaptic plasticity occurs when a synapse changes in strength due to the timing and/or magnitude of chemical signals. This experience-driven phenomenon underlies chronic pain, as the circuits transition from the transmission of nociceptive pain signals to those of chronic pain, divorced from a nociceptive stimulus. Inflammation or trauma can induce remodeling of the synapse within the dorsal horn of the spinal cord, between the primary nociceptive afferent and ascending neuron, leading to the transition from acute to chronic pain (Woolf and Salter 2000). More recent evidence indicates that supraspinal plasticity may contribute to the development of chronic pain. Long term potentiation occurs in ascending pathways (spino-PAG), due to the internalization of neurokinin 1 receptor internalization (Ikeda et al. 2006). Inflammation increases the expression of BDNF within PAG neurons, and that signal is associated with hyperalgesia (Guo et al. 2006).

One mechanism of modifying pain perception is chemical control of the excitability of PAG neurons, as glutamate signaling within the PAG region of the midbrain is essential to producing analgesic effects (Samineni et al. 2017). Several studies have used pharmacological manipulations to alter the responsiveness of both the GABAergic and glutamatergic signaling within the PAG. Blockage of the endocytosis of GluA2 receptors upregulated glutamate receptors on the postsynaptic cell and increased the responsiveness of the postsynaptic cell, resulting in an analgesic effect (Liu et al. 2015). Designer Receptors Exclusively Activated by Designer Drugs (DREADDs), chemogenetic tools used to test the roles of specifically targeted neurons within a circuit, benefit from a lack of cross-reactivity with endogenous receptors and signaling molecules (Roth 2016). DREADD-mediated activation of glutamatergic neurons in the PAG of transgenic mice resulted in analgesia, while activation of the GABAergic neurons in the PAG resulted in a hypersensitivity to painful stimuli (Samineni et al. 2017). In addition to pharmacological manipulations, these circuits can also be achieved using endogenous signals. Capsaicin, which binds to transient receptor potential vanilloid 1 (TRPV1) channels, decreased the responsiveness of both the GABAergic and glutamatergic circuits within the PAG play important roles within analgesia.

Application to Treatment of Chronic Pain

Morphine, an exogenous opioid, is ineffective as a long-term pain management tool due to the development of morphine tolerance, and its overuse is associated with America’s opioid addiction crisis. Morphine tolerance results from the dissociation of µ-opioid receptors from NMDA receptors in PAG neurons (Rodriguez-Munoz et al. 2012). Neuropathic pain can be treated with NMDA blockers (like memantine), but that leads to unacceptable side effects (like confusion and dizziness) due to the lack of spatial specificity of the NMDA blockers and the abundance of glutamate signaling within the CNS. Endogenous opioid signaling does not result in the same tolerance, and deep brain stimulation of PAG leads to hypoalgesia and is associated with the release of endogenous opioids (Sims-Williams et al. 2017).

These recent studies in nociceptive processing have implicated the PAG in a pivotal role in pain modulation. By examining these distinct mechanisms for the elicitation of antinoceptive effects, future treatments for the management of chronic pain may be designed. Recent knowledge detailing the targeting of glutamate receptors and the subsequent alleviation of pain affords the opportunity to explore the extent to which other neurotransmitters play a role in pain modulation. The knowledge that the overall excitation of neurons within the PAG is plastic, and changes in that potential lead to activation of the descending pain inhibitory pathway, could prompt researchers to examine other possible mechanisms or techniques in which activation can be elicited to produce analgesic effects.

Numerous drugs, such as lidocaine, mexiletine, ralfinamide, and ziconotide, which act via blocking voltage gated sodium or calcium channels, are beneficial in the alleviation of some cases of chronic pain. These sodium and calcium channels are present within all neurons, so their blockage is not specific to nociceptive areas of the brain (Perret and Luo 2009). Having discovered the distinct functional roles that the subpopulations of GABAergic and glutamatergic neurons possess in nociception, further assessment of control of neurochemical inputs to the PAG could result in targeted control of pain modulation in the supraspinal areas. Previous knowledge has elucidated the presence of neuropeptides such as substance P, endorphins, and other opiate proteins within the PAG, but recent studies have not been performed in order to prove their functional roles in descending pain modulation (Samineni et al. 2017). Targeting the PAG, through these recently identified pathways, may aid the development of novel treatments for neuropathic pain.

Conclusion

Sensory physiology is an excellent gateway topic to the understanding of neuronal function, neural signaling, and circuits within the nervous system. In nearly a decade of teaching anatomy and physiology at a variety of levels, it has been my experience that discussion of sensory physiology engages students through their real world experience in ways that central processing events, such as disinhibition in the basal ganglia, fail to do as we have limited conscious perception of these events. While vision, taste, and other special senses are engaging to students, the complex process of pain perception has many additional pedagogical benefits.
Pain is a multimodal sense, with defined neural circuits and neuroanatomical structures dedicated to its conscious perception and experience-dependent modulation of that perception, all of which have significant ramifications for human health. These factors result in the presentation of pain experience and pain processing as excellent pedagogical tools in a physiology or neuroanatomy course tasked with teaching students the cellular physiology of neural circuits, the functional significance of neuroanatomical structures, and a clinically-relevant example of neural modulation. As a multimodal sense, pain can be used to illustrate the diversity of environmental stimuli that impinge upon sensory receptors, highlighting the importance of internal and external stimuli. The nociceptive afferents can be used to illustrate a reflex arc, and the nociceptive flexion reflex is included in many anatomy and physiology textbooks to this end.

The purpose of this article is to provide a neuroanatomical and functional framework for the supraspinal modulation of pain to be used by educators illustrating the concepts of plasticity in the nervous system and modulation of sensory perception by the nervous system. Additionally, the pain modulation system provides an excellent opportunity to illustrate pharmacological effects in the brain, and to engage students in discussions of endogenous opioids and exogenous opioids and the opioid abuse epidemic. Specifically, information from this article could be used in a module prompting future medical professionals to design pharmacological agents for electrical interventions to treat chronic pain, including the identification of chemical and/or neuroanatomical targets for intervention in pain management. Additionally, students could be asked to distinguish between interventions that would prevent the progression of acute to chronic pain through the disruption of plasticity resulting in hyperalgesia, and interventions that would result in hypoalgesia after the establishment of chronic pain.

**About the Authors**

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**Literature cited**


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Vaccination Assignment: Anatomy and Physiology Students Practice their Communication Skills by Developing a Pro-Vaccination Brochure Targeting the General Public

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Abstract
Health sciences students need strong communication skills so that they can engage patients, explain concepts and justify medical procedures. For 3% of their final mark, 547 students studying the anatomy and physiology of the immune system were assigned the creation of a one-page brochure to help parents understand the importance and mechanism of childhood vaccination. Students were provided with a list of possible topics (e.g. how vaccines promote active immunity, why childhood vaccination is important, the link between herd immunity and community protection) and asked to explain the physiological bases of those concepts in layman’s terms. Student participation approached 100% and assignment scores averaged 85.0 – 87.6%. Feedback provided to students addressed information quality and accuracy as well as the use of colour, illustrations, and appropriate text to engage readers and convey ideas. Timely provision of feedback to large classes was facilitated by the assignment function of the course learning management system. https://doi10.21692/haps.2019.009

Key words: assignment, communication, soft skills, vaccination, feedback, large classes

Introduction
In addition to a strong foundation in basic sciences such as anatomy, physiology and pathophysiology, healthcare professionals need to develop effective communication skills that will allow them to actively engage with patients, clearly explain concepts related to illness and their treatment, and justify the need for various clinical procedures and medications (American Nurses Association 2010; Schwartz et al. 2019). Be it oral or written, in both instances communication can be defined as delivering critical information in a clear and concise manner (Doherty et al. 2016). While often classified as a “soft” skill (Ray and Overman 2014), communication is nonetheless also recognized by others as core competency that is of paramount importance to collaborative, error-free patient care (Suter et al. 2009). With regard to writing skills, research has shown that nursing students often have gaps in their writing abilities, and that BScN programs should include opportunities to address those gaps in an effort to promote career progression in the years after graduation (Andre and Graves 2013; Feltham and Krahn 2016).

Classic research pertaining to postsecondary education has shown that adults learn best when they can take responsibility for learning that is exploratory and task-oriented in nature rather than via passive attendance at lectures (Knowles et al. 1984; Pratt 1993). Indeed, while traditional approaches with large undergraduate classes have involved the provision of didactic lectures followed by assessment of student learning via multiple-choice-question-based examinations, this approach is not generally viewed as fostering significant long term knowledge retention (Roberts 2011). On the other hand, a number of studies have shown that students who construct their own explanations develop a deeper understanding of important concepts and display improved knowledge retention (Rivard and Straw 2000; Michael 2006). In recognition of these characteristics of adult learners, curricula pertaining to the healthcare professions are often being updated to place increased emphasis on the use of self-reflective approaches that allow students to make connections between theoretical concepts and clinical practice (Bouchaud et al. 2017; DeLenardo et al. 2019).

When encouraging self-directed learning, a concern for educators in the digital age is the wealth of resources available to students with a simple click of the mouse. Rather than jumping from online link to online link and skimming documents to quickly pull out pieces of information, students need to develop deep reading strategies that allow them to critically assess the quality and validity of the information obtained as well as the reliability of their sources (Wolf and Barzillai 2009). Simply said, they need to acquire information literacy (Beck et al. 2012). An assignment that includes individualized feedback addressing the accuracy and completeness of students’ written work can help them develop their research and critical thinking skills. That being said, the logistics associated with efficient and timely provision of that feedback, especially when teaching large undergraduate classes, can definitely pose a challenge.
In this paper we describe the provision of a vaccination-based creative writing assignment to first-year health science students studying the anatomy and physiology of various body systems including the immune system. The learning opportunities linked to this assignment will be described in addition to the effective use of the assignment feature of learning management systems to facilitate assignment evaluation and the efficient provision of individualized instructive feedback.

**Methods**

Two undergraduate classes in anatomy and physiology, ANP1107A (271 students) and ANP1107B (276 students) participated in the study. This project was approved by the University of Ottawa Human Ethics Committee (File number H09-06-10B). Between 55 and 65% of each class was composed of first-year candidates in the BScN program taking this course during their second term of study. The remaining students were distributed primarily among other health science and science curricula (Table 1). At the time of beginning their assignment, these students had already completed the immune system segment of the course (three hours of instruction).

<table>
<thead>
<tr>
<th>PROGRAM</th>
<th>ANP1107A (%)</th>
<th>ANP1107B (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursing</td>
<td>64.6</td>
<td>54.7</td>
</tr>
<tr>
<td>Other Health Sciences Programs</td>
<td>26.9</td>
<td>23.6</td>
</tr>
<tr>
<td>Faculty of Science Programs</td>
<td>6.3</td>
<td>18.1</td>
</tr>
<tr>
<td>Programs within Other Faculties</td>
<td>2.2</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*n = 271 (ANP1107A) and 276 (ANP1107B)*

For 3% of their final grade, students were asked to create a one-page brochure targeting the general public in order to provide educational information pertaining to vaccination, how it works, why it should be done, and against what diseases children can be vaccinated (Figure 1). They were given six weeks to complete the assignment. While students were provided with a list of possible subtitles to include, they were also encouraged to construct their brochure as they thought best, and were given complete freedom to design the brochure layout, including the possible use of supportive illustrations. Within the assignment instructions (Figure 1), students were also informed of the criteria comprising the marking rubric that would be used for assignment assessment. Finally, they were instructed to save the finished product as a PDF file and to submit it via the assignment function of Brightspace®.

**Submission Instructions**

Save your one-page brochure as a pdf. This is essential and the only way in which it can be submitted. Please submit within this assignment web page by attaching your brochure pdf document. The assignment is due by March 30, 10 PM but can be submitted at any time.

**Marking Rubric**

- Quality and accuracy of information (1.5 mark)
- Conciseness of presentation of ideas and ability to grab attention and keep me reading (1 mark)
- Overall layout, use of colour, illustrations, etc. to convey ideas (0.5 mark)
Assignment evaluation was carried out by J. Carnegie (ANP1107A) and J. Savory (ANP1107B). When grading the assignments, it was easy to navigate from one document to the next within the vaccination assignment submission folder of Brightspace and to enter instructive feedback (three to six sentences/assignment) addressing both the strengths of each brochure as well as suggesting areas of possible improvement. After entering a final score out of three, a single click of the “Publish” button sent the score and feedback directly to the student while simultaneously linking these outcomes with the student’s name in Gradebook.

**Results**

Even though assignment completion counted for only 3% of their final grade, participation rates approached 100% for students enrolled in each of the two sections of ANP1107 (Table 2). Furthermore, submission quality suggested that many students worked hard to create documents that were original, engaging, and informative (Figure 2). While plagiarism can sometimes be difficult to recognize, our overall impression was that it was infrequent (less than 3%) and isolated to only a portion of the document in those isolated instances. Whenever found, it was addressed immediately in the feedback to the student and the assignment score reduced appropriately. Students were creative in their use of colour and selection of supportive illustrations, brochure layouts were eye-catching, and information was often presented concisely and accurately. Indeed, about 10% of brochures created by the two student populations were deemed to be of excellent quality; they were so well done that we were hard pressed to come up with suggestions for improvement. Overall assignment averages were 85.0 ± 1.9 and 87.6 ± 0.8 for ANP1107A and ANP1107B, respectively (Table 2), and only three of the 527 students participating in the assignment scored lower than 50% (one student in ANP1107A and 2 students in ANP1107B).

![Figure 2. Example of a vaccination brochure that was well done.](image-url)
Assignment evaluation allowed common student misconceptions to be identified and addressed. Close to 40% of students did not mention the creation of memory cells as a result of vaccination. Some students assigned cellular functions to antibodies, even proposing that antibodies were responsible for immunological memory or were capable of becoming cells, and others had to be cautioned to not personalize vaccines by assigning teaching or thinking roles to them. Approximately 15% of students prepared documents that were too brief and contained insufficient educational content, while 7-8% pitched their educational information at a level that would be too high and too terminology-dense for the general public.

**Discussion**

The fact that each student prepared a vaccination brochure that then needed to be evaluated may raise the concern for instructors of large classes that the provision of individualized feedback to almost 300 students presented an overwhelmingly daunting task. However assignment viewing, the ability to type comments within the assignment function of Brightspace, and immediately send both grade viewing, the ability to type comments within the assignment function of Brightspace, and immediately send both grade and feedback directly to each student greatly improved the efficiency of this process. With regard to other learning management systems, our prior experience with Blackboard Learn® (also equipped with similar assignment-facilitating features) suggests that one important benefit to the use of today’s learning management systems is that they allow us to provide large-enrolment classes with many of the same learning experiences (opportunities to create written work and receive timely feedback) that are offered to students in smaller classes.

**Motivation and communication**

Motivation is a key driving force behind student engagement (Lapum and St-Amant 2016; McDaniel and Tornwall 2016). We suggest that the high level of student participation observed in the present study was driven by both forms of motivation, intrinsic and extrinsic. With regard to intrinsic motivation, it is the learning itself that functions as a reward to encourage continued effort, while with extrinsic motivation, there is an external reward, over and above improved learning, that entices students to engage (Paas et al. 2003; Lapum and St-Amant 2016; Mennenga et al. 2016).

In the current study, the extrinsic motivation was simply the 3% of final grade to be achieved through the development of a product of reasonable quality and educational value. The intrinsic motivation may have been the opportunity to consolidate their understanding of aspects of immune system function by applying that new knowledge through the creation of an educational brochure geared toward the general public. This is a skill that has the potential to serve nurses well once they are out in the workplace and it was hoped that students would see the value in participating in such a profession-related exercise.

Furthermore, the suggested topics that students were encouraged to address when developing their brochures (Figure 1) target several HAPS A & P II learning outcomes at the comprehensive, analysis and application levels pertaining to the immunity and, specifically, the adaptive immune system. Those learning outcomes include being able to distinguish between the primary and secondary immune response, being able to distinguish between active and passive immunity, and using vaccination as a means of stimulating the development of active immunity in order to prevent disease. Studies have suggested that students will participate in learning activities if they can link them to course content, the potential for improved summative outcomes, and/or the acquisition of skills viewed as valuable for their chosen profession (Doherty et al. 2016; Pentaraki and Burkholder 2017). With those goals in mind, the assignment was constructed in order to give students practice in explaining the application of course-related immunological concepts in their own words, developing concise explanations that would fit within a defined space, and using their creativity to present educational information in an engaging manner.

Communication skills were a focus of the assessment rubric in that 50% of the final score was allocated to the ability of the brochure to grab and maintain attention, present information concisely, and package that information in an engaging manner by making effective use of language, colour, and illustrations. Feedback provided to each student not only corrected content errors, but also recognized communication strategies that were particularly effective, and made suggestions for language or layout that could be improved. As a final note, it is worth mentioning that one of the authors (J. Savory) received the following email from a student in ANP1107B in the months after the completion of the course: “The doctor in my neighbourhood is currently using my vaccination assignment as an easy-to-understand flyer in his clinic, which would never have been possible without your course!”. What a terrific, unsolicited piece of evidence linking online learning activities to applicability in the workplace.

**Deep Learning**

Deep learning has been suggested to involve four sequential steps: (1) experience, (2) reflection, (3) abstract conceptualization, and (4) active experimentation or testing (Kolb 1981, Young 2018). Each step uses different areas of the brain and completion of all four steps has been suggested to be necessary for deep learning to truly occur (Zull 2002; Roberts 2011). With regard to the vaccination assignment, most students have experienced both being vaccinated and learning the theory behind vaccination during ANP1107 lectures (step 1). They needed to reflect on what they understood about vaccines (step 2), e.g. how they work and how they confer long term immunological memory, as they planned the layout of their brochure, the information to be included and the order in which that information would be introduced and explained (step 3). Finally, they assembled......
and submitted final products and awaited feedback from a content expert on the success of their endeavors (step 4). An interesting extension of this project would be to compare the depth of understanding and long-term (three to six months) retention of concepts pertaining to vaccination, herd immunity, and the acquisition of immunological memory between students who had developed vaccination brochures and students who did not have the opportunity to engage in this applied activity.

**Limitations**
The scheduling of course content imposed some limitations on this study that made it impossible to use it to its full potential. Presently, the immune system is taught approximately halfway through the course and it made no sense to have students begin their assignment until after learning immunology fundamentals. The necessity to provide students with sufficient time to research and construct their documents meant that they did not submit them until after writing their second midterm exam. This meant that summative evaluation of their knowledge and understanding of the immune system took place **before** they submitted and received feedback on their vaccination assignments. Reception of that feedback, especially with regard to the correction of misconceptions, would have been helpful prior to summative assessment.

A staged assignment in which there is some back-and-forth communication between instructor and brochure creator has the potential to further enrich the learning experience of students as well as keeping them on track with assignment milestones. In theory, the six weeks provided to students for assignment completion should have allowed for some interim assessment and feedback. However, while even one round of feedback partway through the assignment may have allowed timely correction of misconceptions and ensured that students were taking enough time to not only collect, but also analyze and apply their understanding of immunological concepts, the sizes of our classes and our teaching workloads simply did not permit this additional level of communication with students. In the future, we could explore the involvement of a number of graduate students to provide teaching assistance so that interim feedback could be provided quickly and support students while working on their projects.

Finally, the timing of assignment submission combined with the many hours required to grade and provide individualized feedback for almost 300 submissions meant that the course had finished by the time this had been completed. That final scheduling challenge meant that it was not possible to allow students to see and further learn from examples of excellent brochures prepared by their peers. It might be worthwhile to reorganize the content in this course so that the immune system is the first topic to be covered and then saved to be a topic assessed in the second rather than the first midterm exam. That would allow earlier submission of completed assignments and access to feedback before summative evaluation. It would also facilitate the sharing of brochures among members of the class so that they learn, not only from the creation of their own documents, but also by seeing, possibly even peer-assessing, examples of creative thinking used by their colleagues.

**Concluding remarks**
The creation of informative vaccination brochures provided an opportunity for students to apply new knowledge pertaining to the immune system in a clinical application. Students gained practice in explaining concepts in their own words and the assignment function of Brightspace facilitated the provision of individualized instructive feedback to classes with large enrollments. The applied nature of the assignment provided students with experience that should serve them well once they are working in the field of healthcare.

**Acknowledgement**
The authors would like to express their gratitude to University of Ottawa Human Kinetics student Ahmad Abou-Hamde for permission to include his brochure (Fig. 2) as an example of a document that addressed the assignment criteria and was particularly well done.

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**Literature cited**


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