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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/) and available in the Education Resources Information Center (ERIC).

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A Glimpse into the Spring 2022 Edition of the HAPS Educator

As the 2021-2022 academic year draws to a close, it is time, once again, for reflection and for planning. Indeed, I hope to see many of you at the 36th Annual HAPS Conference in Fort Lauderdale later this month. That conference always provides a wealth of new teaching ideas and opportunities for us to share experiences with one another, both in person and as we plan our upcoming submissions to the HAPS Educator. In the meantime, the Spring Edition of the journal provides some important insights into teaching innovations and data supporting the introduction of new approaches to anatomy and physiology education.

This edition begins with four Educational Research articles exploring a variety of topics. The first paper evaluates the ability of i-clickers, a tool used to promote in-class student engagement, to improve student outcomes on anatomy and physiology summative examinations. The second research paper used student survey data to assess the importance of cadaver dissection in preparing students to continue their studies with confidence in schools offering various professional, health-related programs. The third manuscript explores the professional training offered to TAs and suggests ways in which that training should be extended to provide more independence and responsibility so that these students, when they leave with their postgraduate degrees, are better prepared to follow career paths in academia. The final educational research paper switches back to the very beginning of undergraduate studies and explores the importance of online academic orientation in better equipping nursing students for success in undergraduate courses in anatomy and physiology.

A Current Topics paper provides a new way to teach a challenging topic for students: the propagation of action potentials, including such parameters as the influence of axon diameter and the presence or absence of a myelin sheath. The Spring Edition finishes with two Teaching Perspectives manuscripts. The first is a multi-author study exploring the use of carefully planned writing assignments to promote critical thinking by undergraduate students as they explore physiological concepts. The second paper provides detailed descriptions pertaining to the teaching of anatomy online (as many of us have had to do during the past two years) and compares student outcomes with those achieved when learning in person.

As always, I am grateful to all of you who support the HAPS Educator, as authors, as reviewers, as editors, or as digital media experts. And I look forward to reading your submissions as we move through the next few months.

All the best,

Jackie Carnegie, 
Editor-in Chief
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“Even the most experienced clinicians and educators often find that, despite their subject matter expertise, making the transition to virtual instructor can be fraught with difficulties if not preceded by specific training.”
- Dr. Peter Nickless, Northeast College Dean of Online Education
Enhancing Active Learning of Anatomy and Physiology with the Use of i>clickers

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Abstract
One of the most challenging aspects of teaching anatomy and physiology is using teaching tools that enhance active learning and keep students actively engaged during the lecture courses. This study explored the use of a student response system that was easy to use, cost-efficient, and re-usable for multiple anatomy and physiology courses. More specifically, the impact of i>clickers on student performance in anatomy and physiology courses was investigated by comparing exam scores before and after the introduction of i>clickers. This study showed that the use of i>clickers during the lecture courses increased student engagement and improved the performance of students on the lecture exams covering the respiratory, digestive, urinary, reproductive, lymphatic, and immune systems. The overall performance of students in the anatomy and physiology lecture courses had also a tendency to increase. Furthermore, student feedback regarding i>clicker use was highly positive. http://doi.org/10.21692/haps.2022.002

Key words: anatomy and physiology, i>clickers, active learning, student performance, engagement

Introduction
Most educators acknowledge the value of active participation in the college classrooms; however, achieving success in eliciting it seems more difficult despite repeated efforts (Susak 2016; Weaver and Qi 2005). Students struggle with classroom participation due to factors that relate to their personal traits, the classroom size, logistics, seating arrangement, and the formal structure of the classroom environment (Susak 2016; Weaver and Qi 2005).

Similarly to what other educators experienced in other disciplines (Hyde and Ruth 2014; Karp and Yoels 1976; Susak 2016; Weaver and Qi 2005), we and others also noticed that most students remain passive members of the classroom environment during an anatomy and physiology lecture course (FitzPatrick et al. 2011; Geertsen 2015; Hoyt et al. 2010). The low classroom participation rate in our anatomy and physiology courses sparked my interest in implementing a student response system to increase active participation and enhance the learning experience of our students. There is strong evidence for the importance of active participation in class (Lyons 1989; Weaver and Qi 2005). Indeed, students were found to earn higher grades as their classroom participation increased (Handelsman et al. 2005; Rocca 2010). It was proposed that the more students participate, the more they know and comprehend, allowing them to engage in higher levels of thinking (Rocca 2010; Smith 1977).

Classroom participation increases with a student response system because students are able to answer questions anonymously. An interactive classroom response system allows an instructor to present a question to the class, allows students to enter their answers using the clickers, and instantly analyzes, summarizes and displays students’ answers while protecting student anonymity (Beatty 2005; Dufresne et al. 1996). In addition, the immediate feedback provided by an interactive classroom response system technology, such as clickers, has been demonstrated to have a positive impact on student learning (National Research Council 2000; Yourstone et al. 2008). Clickers have been rated as effective learning tools by students enrolled in classes of a variety of levels and sizes (Addison et al. 2009; Caldwell 2007; FitzPatrick et al. 2011).

Mixed results were noticed on student performance in some health sciences courses, when an interactive student response system was used (Caldwell 2007; FitzPatrick et al. 2011). For example, the use of clickers in an exercise physiology course enhanced student performance, whereas in a human pathophysiology course the academic performance of students did not improve with the use of clickers. Furthermore, there is a limited number of studies and, hence, limited data regarding the impact of an interactive student response system on students’ performance in anatomy and physiology courses. For example, one study showed that, in freshmen-level Anatomy and Physiology I and II courses, improvements in quiz performances were observed for some, but not all, lecture material during the clicker years (FitzPatrick et al. 2011). However, another study focused more on the perceptions of students when using a student response system during anatomy lectures, and less on students’ outcomes (Geertsen 2015). The author noted that further investigation is needed to establish if a student response systems can enhance student performance in anatomy courses (Geertsen 2015).

The aims of this study were to: 1) increase classroom participation in anatomy and physiology courses by...
incorporating a clicker system that was reliable, easy to use, cost efficient, and reusable for multiple classes and across semesters, 2) further explore the effects of clicker use on student performance in two sophomore-level undergraduate biology courses (BSCI 21010 Anatomy and Physiology I and BSCI 21020 Anatomy and Physiology II), and, 3) examine student perceptions on clicker use. An important goal of our study was to test the hypothesis that students’ performance in the anatomy and physiology courses would improve if the i>clickers were used during the lectures. The impact of i>clicker use across semesters was evaluated using lecture exams scores and final lecture grades, comparing the years immediately before and after the introduction of the i>clickers. Student perceptions on i>clicker use were also assessed.

Methods

The i>clicker Student Response System

After researching the market for a student response system that would fulfill all our needs, I came across the i>clicker system (https://www.i>clicker.com/) and with the gracious help of the Kent State University Teaching Council, I was able to buy the i>clicker Student Response System to use in my anatomy and physiology courses. This was a one-time purchase and included the instructor kit (presenter kit) with the receiver base and an instructor remote, and a set of 28 student remotes (i>clickers). The software was available to download for free from the i>clicker website, did not require prior installation, was reliable, and most importantly, this i>clicker system was able to be used in multiple anatomy and physiology courses during a semester or during multiple semesters, and there were no fees associated with in-class registration for multiple classes.

The student remotes (i>clickers) were kept in the classroom, in groups of four in a basket, with one basket per table, because each laboratory table could seat a maximum number of 4 students. The student remotes were numbered on the back using permanent marker so that, in addition to the identification number, each i>clicker had a unique number on the back to help with its identification by the students. At the beginning of each semester, students in each anatomy and physiology class chose an i>clicker from the basket and they were then registered, so that each i>clicker was linked with a student name from the roster. A great advantage of using the i>clicker system was to be able to register the student i>clickers in-class for free, for all classes.

Prior to the first lecture course meeting, I integrated my rosters manually by copying and pasting my students’ names in the roster blank document provided by the i>clicker software. When the Roll Call Registration was run in-class, the names of the students appeared on the screen; each name was associated with a two-character code, which my students were able to enter into their i>clickers, to complete the in-class registration of their i>clickers for our course. At the end of the anatomy and physiology course, students would leave their i>clickers in the baskets on the tables.

Study Design

This study included students that were enrolled in two sophomore-level undergraduate anatomy and physiology courses at Kent State University, Geauga campus: BSCI 21010 Anatomy and Physiology I and BSCI 21020 Anatomy and Physiology II. These courses were worth 4 credit hours each, and they were part of the Kent Core Basic Sciences, consisting of combined lecture and laboratory courses. The data for the i>clicker semesters (Spring 2017, Fall 2017, Spring 2018) and for the semesters immediately prior to the i>clicker use (Spring 2016 and Fall 2016) were collected, analyzed, and compared. Importantly, within a given course across time, the instructor as well as the lecture content coverage and quiz/exam format and coverage were all the same. The lecture sections of these courses used i>clickers and all courses had associated laboratory sections which did not use i>clickers. This study was approved by the Institutional Review Board of Kent State University, protocol # 17-030, and informed consent was obtained from all participants.

The weekly 100-minute lecture course was interactive and included open- and closed-ended questions posed by the professor, videos or animations demonstrating a specific topic covered in the lecture, and other active learning activities such as completing Venn diagrams. Toward the end of the lectures, five i>clicker questions were posed that pertained to the lecture material that had been discussed that day and they included multiple choice questions or/and true/false questions (Figure 1). Students were given time (30 seconds) to consider the options (during this time there was peer-peer interaction among the 2-4 students at each table) and then their responses were gathered by the i>clicker system. A histogram showing the response distribution was displayed on the screen together with the correct answer. Discussions followed (student-student interactions between students located at other tables) concerning the rationales for choosing a particular answer and immediate feedback was provided by the professor (direct interactions between the professor and students).

![Figure 1. The teaching strategy.](continued on next page)
The effect of i>clickers on student performance was assessed by comparing exam scores (Bunce et al. 2006; Crossgrove and Curran 2008; FitzPatrick et al. 2011). To complete the lecture portion of the A&P I course, students needed to take four A&P I exams. The topics covered by each of these exams included, as follows: A&P I Lecture Exam 1 covered the general overview of the human organism, anatomical terms, homeostasis, cell biology, tissue, and the integumentary system, A&P I lecture exam 2 covered the skeletal and muscular systems, A&P I lecture exam 3 targeted the functional organization of the nervous tissue, spinal cord, and spinal nerves, and the fourth and final lecture exam tested knowledge of the anatomy and physiology of the brain, cranial nerves, integration of nervous system functions, and the autonomic nervous system.

Similarly to the A&P I lecture courses, the students were evaluated for the retention of the lecture course material in the A&P II lecture courses with the help of four exams, as follows: A&P II Lecture Exam 1 covered the cardiovascular system, including the blood, heart, and blood vessels, A&P II Lecture Exam 2 covered the respiratory and digestive systems, lymphatic system and immunity, A&P II Lecture Exam 3 covered the urinary and reproductive systems, and A&P II Final Lecture Exam tested knowledge of the functional organization of the endocrine system and the endocrine glands.

**Student Survey**

Student perceptions on the degree to which i>clicker use in the anatomy and physiology lecture courses improved their learning was investigated by asking students to complete anonymous surveys at the end of the lecture course. This survey was a modified Student Assessment of Their Learning Gains survey (http://www.salgsite.org/; FitzPatrick et al. 2011) and consisted of 10 questions (Table 1). The scale used to score the answers was: 1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree.

**Data Analysis**

Question difficulty was calculated by dividing the number of students answering that question correctly by the total number of respondents (Osterlind 1998; Tarrant & Ware 2010). A question difficulty factor of less than 0.4 reflected a difficult question, between 0.4 and 0.8 reflected a question of moderate difficulty, between 0.8 and 0.9 reflected an easy question and between 0.9 and 1.0 identified a very easy question (Osterlind 1998; Roschelle et al. 2004). The clicker question difficulty factors were calculated for all i>clicker questions that were used in both A&P I (45 questions) and A&P II (50 questions).

All statistical analyses were performed with the GraphPad Prism, *GraphPad 9.0 Software*, La Jolla, CA, using unpaired t-tests. Data represent the means ± SEM. In addition, data from 88 anonymous student surveys were collected at the end of the i>clicker semesters. The average score and the distribution of responses for each survey question, as well as all responses to the narrative question, were collected and analyzed. All narrative comments were read and rated as positive or negative, counted, and reported as percentages out of the total number of comments.

### Table 1. Student survey.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Participation with clickers increased my feeling of belonging in this course.</td>
<td>1-5</td>
</tr>
<tr>
<td>2. I enjoyed the opportunity to answer a question anonymously.</td>
<td>1-5</td>
</tr>
<tr>
<td>3. Participation with clickers improved my understanding of the subject content.</td>
<td>1-5</td>
</tr>
<tr>
<td>4. Participation with clickers increased my interaction with other students.</td>
<td>1-5</td>
</tr>
<tr>
<td>5. I enjoyed participation with clickers.</td>
<td>1-5</td>
</tr>
<tr>
<td>6. I would recommend using clickers again in this course.</td>
<td>1-5</td>
</tr>
<tr>
<td>7. Was the number of questions asked in each session optimal?</td>
<td>1-5</td>
</tr>
<tr>
<td>8. Participation with clickers improved my grade in the course.</td>
<td>1-5</td>
</tr>
<tr>
<td>9. What would be an optimal number of questions that you would prefer to be asked during each session?</td>
<td>1-5</td>
</tr>
<tr>
<td>10. Please write any comments or suggestions.</td>
<td>1-5</td>
</tr>
</tbody>
</table>
Results

Use of Imp>clickers in A&P I Lecture Courses

To complete the lecture portion of our A&P I course, students wrote four A&P I lecture exams. Although there was a tendency to perform a little better on most A&P I lecture exams, when the average class scores during the i>clicker semesters were compared to the ones when no i>clickers were used, the difference in student performance was not statistically significant (Figures 2B, 2C, and 2D). This trend was noticed for Exam 2 (average class score 83.5 for i>clickers versus 79.5 for no i>clickers), Exam 3 (83.7 for i>clickers versus 82.2 for no i>clickers), and the Final Exam (82.3 for i>clickers versus 78.1 for no i>clickers).

Use of i>clickers in A&P II Lecture Courses

Interestingly, the use of i>clickers during the lecture courses of A&P II classes improved the performance of students on A&P II Lecture Exams 2 and 3 (Figures 3B and 3C). The average class score for Exam 2 was 84.6 when the i>clickers were used versus 76.9, when the i>clickers were not used (p = 0.017, Figure 3B). Regarding Exam 3, the average class score was 88.4 when the i>clickers were used compared to 82.5, when no i>clickers were used (p = 0.0382, Figure 3C). The use of i>clickers did not enhance the performance of students on Exam 1 (Figure 3A). Despite the trend toward increased student performance on the Final Exam when i>clickers were used (the average class score was 112.9), there was no statistically significant difference when compared to the students who did not use i>clickers (the average class score was 108.6, Figure 3D).

Figure 2. Average scores earned by students on the Anatomy and Physiology I (A&P I) lecture exams (n = 33-34 for no i>clickers and n = 31-33 for i>clickers). Mean + SEM.

Figure 3. Average scores earned by students on the Anatomy and Physiology II (A&P II) lecture exams (n = 30-31 for no i>clickers and n = 65-68 for i>clickers). Mean + SEM (*p = 0.017 and 0.0382, respectively).
Overall student outcomes both A&P I and A&P II lecture courses

To evaluate whether the use of i>clickers had a positive impact on the overall performance of students in the anatomy and physiology courses, the final lecture grades earned by students in A&P I and A&P II during the i>clickers semesters were compared to those earned during the no i>clickers semesters. The performance of students in A&P I when i>clickers were used had a tendency to increase when compared to that of students in the A&P I courses when no i>clickers were used (Figures 4A and 4C). The average final lecture grade was 82.3% (with i>clickers) compared to 78.1% (no i>clickers), but this was not a statistically significant difference. Similarly, the performance of students in A&P II courses tended to be enhanced when i>clickers were used (88.1%), when compared to no i>clickers (84.0%; Figures 4B and 4C). Although these differences were not statistically significant, the results showed trends that were encouraging.

Difficulty of i>clicker questions

When we analyzed the difficulty of all i>clicker questions that were used during the A&P I and A&P II lecture courses, we noticed that most of the i>clicker questions in both A&P courses scored in the easy and very easy categories (difficulty factor >0.80) and less than 25% of the i>clicker questions were questions of moderate difficulty (Figure 5). The ability of most students in both A&P I and A&P II to answer the i>clicker questions correctly demonstrated the student gains and the importance of the i>clicker sessions coupled with peer discussions on student performance. These data were in accordance with the increased performance observed on some of the exams.

Figure 4. A) Average final lecture grades of students enrolled in the A&P I when no i>clickers were used (n = 35) compared to when i>clickers were used (n = 33). B) Average final lecture grades of students enrolled in two A&P II when no i>clickers were used (n = 31) compared to when i>clickers were (n=65). C) Actual average final lecture grades earned by students in A&P I and A&P II courses when no i>clickers were used, compared to when i>clickers were used (mean ± SEM).

Figure 5. Difficulty of i>clicker questions used in A&P 1 (A; 45 questions) and A&P II (B; 50 questions). A difficulty factor of less than 0.4 reflects a difficult question, between 0.4 and 0.8 reflects a question of moderate difficulty, between 0.8 and 0.9 reflects an easy question and between 0.9 and 1.0 reflects a very easy question.
Students’ perception of i>clicker use

Of the 98 students completing the A&P I and II courses when the i>clickers were used, 82 students completed the survey, for an overall response rate of 83.7%. A&P I and A&P II courses did not differ greatly in the student responses. The mean ratings ranged from 3.8 to 4.4 for the A&P I course (Figure 6A and Table 2) and between 3.7 and 4.6 for the A&P II courses (Figure 6B and Table 3). It was also exciting to notice that all questions that reported one mode were scored as 4 or 5 (Tables 2 and 3). In conclusion, student’s perception on the i>clicker use in the anatomy and physiology courses was highly positive, showing that the students enjoyed the use of i>clickers in our anatomy and physiology courses and they felt that the i>clicker system enhanced their active learning, participation, and sense of belonging in the class.

![Image of Figure 6](image-url)

**Figure 6.** Perception of A&P I (A) and A&P II (B) students regarding the use of i>clickers in response to the first 8 questions of the survey (Table 1).

<table>
<thead>
<tr>
<th>Table 2. Mean and mode scores of the first 8 questions of the survey from the A&amp;P I students.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;P I</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>SEM</td>
</tr>
<tr>
<td>n</td>
</tr>
<tr>
<td>Mode</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3. Mean and mode scores of the first 8 questions of the survey from the A&amp;P II students.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;P II</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>SEM</td>
</tr>
<tr>
<td>n</td>
</tr>
<tr>
<td>Mode</td>
</tr>
</tbody>
</table>
When students were asked for their input regarding the optimal number of questions that they would prefer to be asked during a lecture session (question 9 of the survey), 71.4% of students answered that 5 questions would be optimal, 27.1% mentioned that they would prefer more than 5 questions per session, and only 1.4% suggested less than 5 questions (Figure 7A). For the narrative question (question 10 of the survey), 80.8% (n=21) of students responded to this question with a positive comment, whereas only 19.2% (n=5) had a negative comment (Figure 7B). Samples of the positive and negative comments are shown in Figure 8. The negative comments were referring mainly to not having enough questions or needing more time to complete or discuss the i>clicker questions.

**Figure 7.** Student responses to the last two questions of the survey (Table 1).

---

**Samples of Positive Comments**

- I liked how the clicker questions gave us a little insight as to what the main ideas of the chapter were.
- Loved the clickers! Helped improve my knowledge.
- Loved the clickers! So much fun and interactive.
- Thank you for a great year!
- This learning tool could be used in other courses as well.
- It helped me in applying what I learned.
- Overall a great learning environment!
- I feel that when I got an answer wrong, I remembered the correct answer better when we took the quiz [test].
- Improved my grade.
- Continue clickers.
- I thought it was very helpful
- I enjoyed the use of the clickers. It was almost equivalent to a mini-review session when we used them. This helps to "cement" the concepts into your brain.

**Samples of Negative Comments**

- Having to answer 5 questions correctly for 1 point really is not worth it.
- I wished there were more questions to show understanding of full material and more time to complete the quiz and understanding "why" to learn the correct answers and reasoning.
- Just wished we had more time to really take in the clickers. I know I couldn’t stay some of the time because I had to get to work.

---

**Figure 8.** Samples of positive and negative comments received from students in response to the narrative question of the survey.
Discussion

Although there is a general consensus regarding the benefits of using a student response system in the classroom and these benefits have been discussed widely in the literature (Beatty 2005; Caldwell 2007; National Research Council 2000; Poulis et al. 1998; Roschelle et al. 2004; Solomon et al. 2018), there is still limited data regarding the use of clickers in undergraduate anatomy and physiology courses. In this study we focused on incorporating the i>clicker system into two sophomore-level anatomy and physiology courses to increase active participation of our students during the lectures; we also explored the effects of clickers on student achievement and examined the student perception on the i>clicker use.

The students who usually register for the A&P I and II courses at the Kent State University, Geauga campus, are very diverse: some students are traditional students, and some are non-traditional students. Some are first-generation students, and some are not first-generation students. Taking into account the diverse backgrounds of our students, as well as the challenges of an anatomy and physiology course (an intense course that requires a lot of memorization), it was important to find an approach to increase classroom participation because students who actively participate in the learning process have been shown to learn more than those who do not (Tinto 1997; Weaver & Qi 2005).

As Dunham (2011) noted, due to the variety of students in a class, it is often very difficult for a professor to incorporate teaching strategies that would make every student an active participant. Notably, a student response system provides all students in a class with the opportunity to actively participate in the learning process, which has been shown to increase student performance (Poulis et al. 1998). The no-cost, web-based tools that were available online and could have been used in a classroom relied on the use of smart cell phones, tablets, or laptops. Due to the diverse socioeconomic status of our students, those tools were not incorporated in our anatomy and physiology courses because not all our students had access to an internet-connecting device or a smart phone.

The i>clicker system that was incorporated in our anatomy and physiology courses as a student response system was a one-time purchase and we were able to use it with multiple classes. With most student response systems, students need to buy their own clicker; however, with the i>clicker system we were able to keep the educational costs of our students low by keeping a set of i>clickers in the classroom. Moreover, this approach also eliminated the possibility of students forgetting to bring their own clicker to each lecture since the i>clickers were provided to them. In addition to its re-usability and ability to register each student i>clicker in-class for free for multiple classes each semester and across years, the i>clicker system also presented the ability to be used for testing and to view the results of the i>clicker sessions in an anonymous way, increasing student participation and engagement, and extending the opportunity to provide immediate bidirectional student-professor feedback.

According to Roschelle and colleagues (2004), a student response system has the ability to facilitate a classroom network or a community-centered environment because it “connects the learning of each student with the learning of the group and provides helpful feedback to each student, while giving the teacher a rapid insight into the current level of understanding in the classroom.”

The i>clicker sessions kept the students motivated, focused, and engaged with the lecture material. Each i>clicker session had the format of a short quiz during which students were able to collaborate in small groups of two to four students. Four has been suggested to be the largest number of students that can interact comfortably (Felder & Brent 2009). Active learning occurred during these i>clicker sessions via both peer-to-peer and professor-student interactions. Felder and Brent (2009) defined active learning as “anything course-related that all students in a class session are called upon to do other than simply watching, listening, and taking notes”. The i>clicker sessions actively engaged the learners by shifting the focus of teaching away from knowledge transmission to knowledge construction (Singh et al. 2019).

The majority of the i>clicker questions tested student knowledge and comprehension of the lecture material. While these are basic levels of Bloom’s taxonomy (knowledge and comprehension), they are an essential part of learning anatomy and physiology and necessary prerequisites for moving forward with questions that help evaluate deeper understanding, such as application of knowledge and analysis (Crowe et al. 2008). When we examined the difficulty of all i>clicker questions (Osterlind, 1998), we found that most of them in both A&P I and A&P II courses were answered well (difficulty factor >0.80) and less than 25% of the i>clicker questions were moderate questions (difficulty factor 0.4-0.8). These results are in accord with the positive impact on student achievement we observed during the i>clicker semesters.

In this study we showed that the use of i>clickers during the anatomy and physiology lecture courses improved the performance of students on some lecture exams and showed a trend toward improvement for others. Together these data indicate that incorporating the i>clicker system into the anatomy and physiology courses enhanced the active learning of anatomy and physiology by engaging students in the learning process, increasing participation, focus, and motivation.

In addition, the use of the i>clicker system during the lecture courses tended to improve overall student performance in the lecture portions of both A&P I and A&P...
Enhancing Active Learning of Anatomy and Physiology with the Use of i>clickers

Il courses. We were able to compare the results of the no i>clicker semesters with the i>clicker semesters because all anatomy and physiology courses were taught by the same professor, using the same lecture material, and the same format of the course. Even though the overall increase in student achievement was not statistically significant, the trends showing higher average final lecture grades when i>clickers were used were encouraging. Other studies have also shown some variability in terms of student performance between various portions of a course or between various courses (Caldwell 2007; Crossgrove & Curran 2008; FitzPatrick et al. 2011).

It is hard to isolate a single intervention when evaluating student outcomes. For example, the fact that we did not observe a higher performance on the A&P I lecture exams when i>clickers were used could be explained by the fact that the professor teaching these courses already had incorporated other active learning tools, such as the use of Venn diagrams, before beginning the use of i>clickers. It is also possible that more time dedicated to the i>clicker sessions and peer instruction (Crouch & Mazur 2001) could have had a greater impact on overall student performance. This approach could be considered in the future.

However, we need to keep in mind that the anatomy and physiology lecture courses are intense courses during which a professor needs to cover a lot of lecture material. Therefore, finding the time to increase the duration of the i>clicker sessions could be challenging. As Poulis and colleagues (1998) observed in physics classes, increased active participation of students during a lecture course is one of the factors that could explain the positive effects of clickers on student performance. Other factors may also be important for facilitating learning such as an increased course structure in the form of weekly short quizzes. Quizzing not only serves as an evaluation tool; formative assessments have been shown to promote effective learning via the “testing effect” (Freeman et al. 2011; Orr & Foster 2013; Walck-Shannon et al. 2019).

Therefore, in addition to making each student an active participant in the learning process, it is also possible that our i>clicker sessions may have supported learning through the testing effect. It would be interesting in the future to evaluate the effect of increasing the number of i>clicker sessions during a lecture course and also evaluate if re-quizzing has an impact on student performance and knowledge retention in our A&P courses (Walck-Shannon et al. 2019).

Similarly to what others have found regarding student feedback on the use of a student response system (Addison et al. 2009; Caldwell 2007; Draper 2002; FitzPatrick et al. 2011; Geertsen 2015; Kay & Knaack 2009), the perception of students enrolled in the A&P I and II courses on the i>clicker use was highly positive and consistent across semesters and courses. The overall response rate of student completing the survey was very good. Students agreed that using the i>clickers during the lecture course increased their sense of belonging in the course. Students also agreed that i>clicker use increased their participation, allowed them to answer questions in an anonymous fashion, improved their understanding of the lecture material, promoted interactions with other students, and they both enjoyed and recommended continued i>clicker use. The majority of students responded to the narrative question (question 10 of the survey) with a positive comment and agreed that having five i>clicker questions was the optimum number to use per lecture. Interestingly, the fact that almost 30% of the students wished that there were more than 5 i>clicker questions per lecture demonstrated that students greatly appreciated the use of i>clickers as part of their learning journey, and that we may need to find ways to allocate more time to the i>clicker sessions in the future.

Conclusions

The results of this study demonstrated that the use of clickers during lecture courses had a positive impact on active learning, student engagement, participation, and academic performance. These data, together with the highly positive student feedback and the advantages of the i>clicker system, including its cost-efficiency, reliability, versatility, and reusability for multiple classes during a semester, or during multiple semesters, motivate us to continue using this student response system in our anatomy and physiology courses. These results also give us hope that we could also increase student performance, in general, by incorporating the i>clicker system in other courses, especially during the post pandemic times when more and more courses will return to their traditional face-to-face teaching format.

About the Author

Daniela Popescu is an Associate Professor at Kent State University, Geauga campus. She earned her MD degree from Carol Davila University of Medicine, Bucharest, Romania, in 1998, and her PhD degree from Vanderbilt University, Department of Pharmacology, Nashville, TN in 2006. She has been teaching Anatomy and Physiology and Human Biology courses at Kent State University, Geauga campus, since Fall 2013. In Fall 2015, she received a Faculty Recognition Award from the Kent State University Teaching Council. In 2021, she was awarded a Gold Teaching Recognition Award from the Center for Teaching and Learning at Kent State University.

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Usefulness of a Cadaver-Based Dissection Course as Perceived by Matriculants in a Professional School

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Abstract
We examined the perceived adequacy and effectiveness of BIO 0475, Advanced Human Dissection, in preparing undergraduate students for the transition into gross anatomy (or equivalent) during their first year of professional school. A 16-item, electronic survey was distributed to course graduates (n=18) that evaluated 1) the importance of BIO 0475 as it related to gross anatomy, 2) student preparedness as provided by their undergraduate training, and 3) perceived level of comfort with adapting to the increased demands of professional school. Students reported the course as beneficial to their professional studies and improving their perceived preparedness for the demands of gross anatomy at the professional level. The development of the Advanced Human Dissection course is reported as a benefit to the students as they matriculate into their professional studies.

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Key words: Cadaver, undergraduate, anatomy, dissection, professional school

Introduction
Anatomy is recognized as a central core of medical and dental education (ADEA 2018; Louw et al. 2009). Although admissions requirements vary, there is currently no global requirement for anatomy as a prerequisite for medical or dental schools in the United States (AACOM 2022; AAMC 2021; ADEA 2018). For undergraduate students, human anatomy and combined human anatomy and physiology courses are historically difficult, as these courses require a significant time investment on the part of the student and extensive mastery of anatomical language in order to be successful (Daempfle 2003; Hopper 2016). Despite this, many undergraduate students interested in professional schools elect to complete these courses as prerequisites, primarily based on advisement of school faculty and medical educators (Finnerty et al. 2010). Interestingly, completion of anatomy prerequisites does not always translate immediately to success in gross anatomy at the professional level (Robertson et al. 2020). Multiple reports have indicated varying outcomes for students possessing premedical coursework in anatomy (Binstock and Junsanto-Bahri 2014; Forester et al. 2002; Kondrashov et al. 2017; Peterson and Tucker 2005; Robertson et al. 2020). Comparisons of students with prior anatomy exposure noted no statistical difference in cumulative grade-point averages for the first year in medical school or in the students’ scores in the medical courses examined. This was also consistent when analyzing performance among students in the upper and the lower quartiles (Canaday 1985). In contrast, Forester and colleagues (2002) found that students with premedical gross anatomy and/or histology coursework show improved academic performance in corresponding medical school courses, with premedical exposure to prosected anatomical specimens significantly improving academic performance in medical gross anatomy.

More recent reports have outlined the number of anatomy prerequisites as having an impact on performance in gross anatomy in medical school. Kondrashov and colleagues (2017) reported that having three premedical anatomy prerequisites, including one with dissection experience, resulted in significantly higher performance in anatomy. Various reports have highlighted the importance of anatomy content knowledge as reported by students and residents, residency directors, and dental professionals (Bakr et al. 2017; Binstock and Junsanto-Bahri 2014; Farey et al. 2014; 2018). Supporting the increased exposure of prior anatomical coursework as a key factor for success in professional school, a study surveying medical students in Australia denoted six factors positively associated with increased confidence as medical students: vertical anatomy integration, frequency of anatomy assessment, integration of anatomy with basic sciences, male gender, anatomy instruction prior to medical school, and exposure to dissection (Farey et al. 2018). Indeed, there have been previous calls to develop recommendations that explicitly outline the core anatomy knowledge needed for medical students at various professional stages of development (Farey et al. 2014).
Missouri Southern State University is a small liberal arts university with an enrollment of approximately 5,500 students. A range of anatomy courses are offered to students, including Human Anatomy, Anatomy and Physiology I/II, and Comparative Vertebrate Anatomy. These courses served as electives for pre-professional (pre-medical, dental, pharmacy, physician associate, veterinary) and health science (pre-nursing, dental hygiene, radiologic technology) students before matriculating into their respective programs. These courses utilized models, anatomical software, cat dissections, and bovine and sheep specimens to progress through the required anatomical structures. In light of the demands of gross anatomy curricula in professional schools, the university installed a cadaver dissection suite on campus in 2011 and incorporated prospected human specimens into the undergraduate anatomy courses.

To take full advantage of this new cadaveric facility, a novel dissection-based course, BIO 0475 – Advanced Human Dissection, was created for highly-motivated pre-professional students to complete as part of their undergraduate degree. The course was conceived as an advanced exploration of human anatomy designed to prepare students for professional school or specialized graduate study. The course format involves both lectures and laboratory sessions each week, with the lectures providing the conceptual and organizational framework for laboratory experiences that emphasize cadaveric dissection supplemented with anatomical software. Requiring pre-requisite coursework in Human Anatomy, Human Anatomy & Physiology II (the second course of a Human Anatomy & Physiology course sequence), or Comparative Vertebrate Anatomy ensured that students had adequate exposure to critical terminology and fundamental principles. Students qualified for enrollment through a selection process based on academic coursework and organizational framework for laboratory experiences. Applications were reviewed with a minimum grade of C or better, as well as presenting their reasoning and motivation for participating in BIO 0475. Enrollment into the course was selective and limited to no more than 8 students per semester. Requirements for entry included completing an anatomy prerequisite course in Human Anatomy, Human Anatomy & Physiology II, or Comparative Vertebrate Anatomy with a minimum grade of C or better, as well as presenting their reasoning and motivation for participating in BIO 0475. The course was advertised to all Biology majors, as well as Biochemistry and Nursing majors. Applications were reviewed and selected by the anatomy faculty at Missouri Southern and successful applicants were enrolled in the course by the department chair.

Cadaveric donors (n=2) were obtained each semester from the Gift Body Program at Kansas City University, Kansas City, MO. Four students were assigned to each donor for the semester. The course utilized a regional approach divided into the following five units: Unit One - posterior torso, neck, gluteal region, Unit Two – extremities, Unit Three – thorax, Unit Four - abdominopelvic cavity, and Unit Five - head and anterior neck. The same instructor led the lecture and laboratory sessions. The donors were treated as the student's first patients.

**IRB Approval and Data Collection**

IRB approval was obtained through the MSSU IRB committee (#985985-1). Students who completed BIO 0475 from Spring 2013 through Fall 2014 (n=36) were requested to complete an
electronic Likert scale questionnaire with items addressing the perceived benefit, recommendations for, and expected grade outcomes from their professional coursework. A single open-ended item was included to provide an opportunity for qualitative feedback. All submissions (including comments) were anonymous. The survey was distributed in 2016 via SurveyMonkey (Momentive, San Mateo, CA), with participants initially consenting to the survey prior to reviewing and answering any survey items. Responses were received by 18 of the 36 students (50%) who had completed BIO 0475.

Data Analyses
Quantitative data were collected and analyzed using Microsoft Excel (Microsoft Inc., Seattle, WA). Likert data were not normally distributed, therefore, medians and standard deviations for each group were calculated. Qualitative comments were analyzed for relative usefulness and preparing the alumni for professional school. Open-ended responses describing the usefulness of the course were coded by the authors. A code is a word or short phrase generated by the researcher to summarize the essence of a qualitative datum; descriptive codes were applied to the data to summarize responses provided by participants (Saldana 2016). Percent frequencies and Chi-square analysis of the frequencies were calculated. Four categories of codes were applied to the responses: (1) positive accolades; (2) perceived advantage in the future; (3) recommendation to future students; and (4) clinical relevance. Direct quotes included as examples are verbatim from survey responses.

Results
The Advanced Human Dissection course was reported as a benefit to students as they matriculated into their professional studies. Quantitative analysis of student responses to Likert scale questions specific to the perceived benefits of BIO 0475, including improved ability to adjust to the demands of professional studies and feeling more prepared in comparison to their peers, are presented in Table 1. The majority of respondents strongly agreed (n=16) that BIO 0475 had a perceived benefit to their professional studies. Those strongly agreeing with the perceived impact on their subsequent grade in gross anatomy (or equivalent) specific to their professional program dropped slightly (n=14). BIO 0475 course grades and the expected grades for respondents for their gross anatomy course in a professional school are reported in Table 2. Interestingly, a majority of students (n=13) also indicated that their peers expressed a desire to complete a dissection-based course prior to entering a professional school. The clinical component of the course was reported as helpful to future professional studies (n=12), but almost one-third of respondents (n=5) were neutral on the level of significance (Table 1). Respondents did not report any preference for the prerequisite needed to be successful in BIO 0475 (data not shown).

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Median (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I found the advanced human dissection course to be beneficial to my professional studies</td>
<td>16</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4.77 (± 0.01)</td>
</tr>
<tr>
<td>I felt more adequately prepared than my peers because I had completed a cadaver-based dissection course</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.77 (± 0.12)</td>
</tr>
<tr>
<td>I was better able to adjust to the demands of professional school due to BIO 0475</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>4.77 (± 0.05)</td>
</tr>
<tr>
<td>My peers expressed a desire to have also completed a dissection course before entrance to professional school.</td>
<td>13</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4.77 (± 0.10)</td>
</tr>
<tr>
<td>I believe BIO 0475 positively impacted my grade performance in gross anatomy (or its equivalent).</td>
<td>14</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>4.77 (± 0.16)</td>
</tr>
<tr>
<td>The clinical component of BIO 0475 was extremely helpful in my professional studies.</td>
<td>12</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>4.77 (± 0.38)</td>
</tr>
</tbody>
</table>

Table 1. Survey addressing perceived benefit and impact of BIO 0475, Advanced Human Dissection (n = 18 respondents).
Student responses to Likert scale questions specific to recommendations of BIO 0475, including the usefulness to future students and increasing the structure list and/or number of donors, are reported in Table 3. All respondents (n=18) indicated that they strongly agreed with recommending BIO 0475 to all pre-professional students. The distribution of responses specific to the number of donors and the breadth of the structure list varied. The majority of students either strongly agreed (n=7) or agreed (n=7) with increasing the number of donors. Fifty percent of the respondents (n=9) were neutral regarding the breadth of the structure list and about one-third (n=5) recommended an increase in length.

Qualitative feedback

Responses (n=13) from the open-ended survey item were coded qualitatively following Saldaña (2016) and reported in Table 4. The two highest categories were those that included positive accolades (53.8%) and those that perceived a future advantage (53.8%) from the course. The first category included responses from students who gave accolades specific to their level of enjoyment for the course:

“I absolutely loved this class! I was so fortunate to have had the opportunity to learn so much, from such a great instructor. I would highly recommend this course to any student pursuing higher medical education.”

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Median (± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I would recommend the Advanced Human Dissection course to all pre-professional students.</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.00 (± 0.00)</td>
</tr>
<tr>
<td>I would recommend an increase in the number of cadavers for dissection in the course.</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4.00 (± 0.17)</td>
</tr>
<tr>
<td>I would recommend an increase in the breadth of structure lists in the BIO 0475 course.</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>2</td>
<td>0</td>
<td>2.61 (± 0.78)</td>
</tr>
</tbody>
</table>

Table 3. Survey regarding recommendations specific to BIO 0475, Advanced Human Dissection (n = 18 respondents).

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent Response</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive accolades</td>
<td>53.8% (7)</td>
<td></td>
</tr>
<tr>
<td>Perceived future advantage</td>
<td>53.8% (7)</td>
<td></td>
</tr>
<tr>
<td>Recommendation to future students</td>
<td>38.5% (5)</td>
<td>0.001</td>
</tr>
<tr>
<td>Clinical relevance</td>
<td>23.1% (3)</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Qualitative Categories applied to Responses from the Open-Ended Survey regarding BIO 0475 (n = 13 responses).

Table 2. Grade outcomes in BIO 0475 and final or expected course grades upon completion of a gross anatomy course in a professional school.
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The second category of responses were specific to the perceived future advantage students felt the course contributed to their professional studies. A specific example highlights the perceived benefit:

“The course was more than helpful. It was an EXCELLENT experience. I cannot imagine entering medical school without this exposure. Many of my peers in medical school were jealous of my experience and I was often able to take the lead on team dissections. I would definitely recommend or even require this course for students wishing to enter medical school.”

The third category of responses (38.5%) were specific to students recommending the cadaver dissection course to all pre-professional students. These responses were made independent of Likert question(s) already included in the survey.

“I think it’s a great undergraduate course to prepare for a graduate anatomy class. I felt very prepared for lab in my graduate course thanks to this class.”

The final category emphasized feedback specific to the clinical component to the course (23.1%). Many noted the application of pathologies found in the donor as it corresponded to course content:

“I greatly appreciate the clinical relevance and applications incorporated into the course. Overall, I couldn’t be more thankful for the opportunity to take this course.”

Specific suggestions for improvement related to the inclusion of: 1) more clinical content, 2) structures of the hand, and 3) osteology surface features and attachments.

“We needed to learn the various surface names, and what purposes they served (insertions). Having had advanced human dissection, grad school Anatomy was more like a review, and I was able to focus more on the advanced topics, like nerve pathways, origins and insertions, and worried less about gross structures.”

Discussion

Results of the current study indicate that completion of a cadaveric dissection course was perceived as beneficial by students who subsequently enrolled in professional programs. Students indicated they could focus on other study habits instead of having to devote time to becoming comfortable with working with cadavers and dissection.

Nwachukwu and colleagues (2015) reported that the quality of dissection completed by students is associated with higher scores on practice as well as final practical examinations, supporting the role of working through the layering of organs in promoting a better understanding of structural relationships and spatial organization. Considering the role that a complete, dedicated dissection has for the performance of the dissector, a similar principal can be applied to the undergraduate student who completes a team-based dissection course.

Thompson and Griffin (2021) reported differences in assessment outcomes among undergraduate and medical students in a gross anatomy course, suggesting that dissection can provide a cognitive load similar to medical school for matriculating students. Collectively, the medical students performed better on higher- and lower-order written assessments, despite similar time spent per question. A larger difference in scores was identified on practical questions, and this was accounted for by the heavy laboratory load in the gross anatomy training of medical students.

Students in BIO 0475 get an early preview of this cognitive load, and, while we cannot follow their specific performance in professional school, the general improvement in self-confidence based on the dissection experience provided by BIO 0475 suggests that a positive correlation is likely.

Further, we have begun documenting and emphasizing the clinical anatomy and pathology of the cadavers as part of the BIO 0475 course curriculum. It is imperative that we recognize the value of a human dissection course at the undergraduate level in adequately preparing students for the transition into professional school. As such, we have begun advising all pre-professional students to complete the Advanced Human Dissection course. This has created small, but welcome challenges due to the positive course feedback, as well as the popularity of the experience as shared among students. To accommodate the increased demand, the cadaver laboratory was physically expanded to house eight whole-body donors. This has allowed us to offer the course twice per academic year and with the added donors, the course enrollment was simultaneously increased to 16 students. Future studies will be able to be implemented due to a higher number of students and increased frequency of the courses.

Does the Dissection Experience Increase Self-Efficacy?

The theory of self-efficacy defines perceived self-efficacy as “people’s judgments of their capabilities to organize and execute a course of action required to attain designed types of performance.” (Bandura 1986). An individual with high self-efficacy perceives themselves to have the skills to be able to succeed at the task at hand; it is self-perception of capability (Morris 2004) and impacts student motivation and a number of academic behaviors (Cavallo 2004). Perceived anatomical self-efficacy includes an individual’s judgment of his or her ability to complete tasks such as dissecting, learning anatomical knowledge, and applying anatomical knowledge to clinical situations, and has been shown to be highly predictive of student performance on practical exams (Burgoo et al. 2012).

Interestingly, McNulty and colleagues (2016) reported the benefit of pre-matriculation course work in evaluating success in a veterinary program. Students participating in a week-long pre-course in canine thoracic extremity anatomy resulted in significant improvement on examinations throughout the academic year, with a distinct improvement in scores on the exam that corresponded to the pre-course material.

continued on next page
Additionally, analysis of qualitative comments from a similar study examining the role of a pre-course experience on veterinary anatomy examinations revealed middle (60-79%) and lower (≤ 59%) tiers of students identified specific benefits related to self-efficacy including, skill acquisition (study and dissection skills), impact of course environment (hands-on experience, familiarity of learning environment, course structure), and exposure to anatomic knowledge (improved anatomy learning, exposure to anatomic language) (McNulty and Lazarus 2018). Collectively, these data provide evidence that recommendation or requirement for anatomy-related coursework before matriculating into professional programs is beneficial to the students’ experience due to positive reinforcement of their self-efficacy (McNulty and Lazarus 2018; McNulty et al. 2016).

Similarly, students in the present study who completed the Advanced Human Dissection course would likely score higher on self-efficacy assessments as suggested by their willingness to apply for, enroll in, and complete the dissection course with the purpose of having a perceived better chance of admission into a professional program. Indeed, the dissection capabilities learned in the course reduced the slopes of learning curves once these students were enrolled in professional schools and increased their self-efficacy for future tasks.

Student engagement has been suggested as one of the most important predictors of student success (Reinke 2019). Pizzimenti and Axelsson (2015) also characterized the correlation of academic performance with the Motivated Strategies for Learning Questionnaire (MSLQ) and demonstrated that greater use of learning strategies by a given student were associated with a higher level of performance in a gross anatomy course. Indeed, significant differences were identified in self-perceived preparedness by students who had participated in problem-based-learning activities coupled with cadaveric dissection, as compared to individualized learning activities (Thompson et al. 2019).

Although we did not measure the students’ learning strategies with the MSLQ, the application barrier to course enrollment served somewhat as an indicator of the level of interest and engagement on behalf of the student. As such, the active learning and engagement involved in completing the course dissections potentially translate to improved anatomical self-efficacy. It would be of special interest to evaluate the self-efficacy of students before and after completion of BIO 0475 to determine the course’s impact on students’ own feelings of success.

A more recent report evaluating previous exposure to anatomical knowledge compared to academic performance in occupational therapy did not find a correlation (Giles 2021). However, statistically significant correlations were reported, including perceived preparedness and the perceived benefit of an anatomy review course. Indeed, an overwhelming majority of students (92%) indicated they would have benefited from and participated in an anatomy review, suggesting that pre-course experience and/or an anatomy review course may or may not directly impact student outcomes, but can positively impact students’ self-efficacy.

The development of the Advanced Human Dissection course is reported as a benefit to students after their matriculation into professional programs. Furthermore, we have begun documenting and emphasizing the clinical anatomy and pathology of the cadavers as part of the BIO 0475 course curriculum. It is imperative that we recognize the value of a human dissection course at the undergraduate level in adequately preparing students for transition into professional schools. At our institution, we currently advise all pre-professional students to complete the Advanced Human Dissection course and will continue to analyze the perceived usefulness of this course in the future.

**Acknowledgment**

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**About the Authors**

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Usefulness of a Cadaver-Based Dissection Course as Perceived by Matriculants in a Professional School

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Directing a Study Skills Course as a Graduate Student Develops Flexible, Autonomous, Student-Centered Educators

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Abstract
The historical dearth of qualified anatomy educators has been thoroughly discussed in the literature. In recent years, several graduate, postdoctoral, and continuing education programs focused on anatomy education have emerged at various institutions specifically designed to meet the growing demand for qualified anatomy faculty. While these programs provide students with courses and experiences that facilitate the transition to faculty, many graduate students do not get the opportunity to be a course director during their time as a graduate student, despite the fact that many of these individuals will enter into teaching-intensive faculty positions upon graduation. This phenomenological study seeks to describe the experiences of individuals who taught a study skills course at a large midwestern university to undergraduate anatomy students. The individuals were interviewed to discuss their experiences directing the course, which ranged anywhere from one to six semesters. The interviews were recorded and transcribed, and thematic analysis of the transcripts revealed four primary themes: flexibility, autonomy, student-centered, and broader pedagogical impacts. This opportunity allowed them to structure their own course, helped them interact and communicate with students better, and allowed them to implement activities in the classroom based on their personal pedagogical and research interests. It also promoted the development of skills and knowledge needed by aspiring educators and better prepared them for their future faculty positions. Such an experience is worth offering graduate students, when possible, to facilitate the transition from student to faculty member. http://doi.org/10.21692/haps.2022.009

Key words: graduate students, phenomenology, thematic analysis, study skills, graduate teaching assistants

Introduction
There is a well-documented dearth of qualified anatomy educators (Blevins and Cahill 1973; Eldred and Eldred 1961; Holden 2003; McCuskey et al. 2005; Schaefer et al. 2019). This lack of trained anatomy educators resulted from an increased emphasis on more research-focused faculty and a decreased emphasis on education-focused faculty (Shortlidge and Eddy 2018). Additionally, in the 1990s, doctoral training programs in neurobiology and anatomy altered their graduate curricula by replacing anatomical science courses with courses in cell and molecular biology (Richardson-Hatcher et al. 2018). As a result, faculty members hired were well-equipped to meet institutions’ research expectations, while lacking in preparedness to teach gross anatomy (McCuskey et al. 2005). Because of this heightened focus on researchers, many institutions have failed to adequately invest in their anatomy departments, leading to an aging population of anatomy faculty (Fraher and Evans 2009). As classically trained anatomists have begun to retire in recent years, academia continues to experience a shortage of qualified educators and an increase in adjunct and sessional instructors (Caruth and Caruth 2013; Doss and Brooks 2016; Halcomb et al. 2010; Rhodes et al. 2018; Schaefer et al. 2019). Furthermore, the growth in graduate and undergraduate health science programs only serves to exacerbate this need for qualified anatomy educators (Doss and Brooks 2016; Wilson et al. 2020a). The pressing demand for anatomists is not isolated to institutions in the United States, but rather, is an issue faced by institutions worldwide (Chia and Oyeniran 2020; Memon 2009).

In recent years, several graduate (Albertine 2008; Brokaw and O’Loughlin 2015; Richardson-Hatcher et al. 2018; Walker and Ward 2007), postdoctoral (Bader et al. 2010; Fraher and Evans 2009), and continuing education (Doss and Brooks 2016) training programs specifically focused on anatomy education have emerged at institutions across the United States, as well as in Canada and Europe (Schaefer et al. 2019; Wilson et al. 2020b). The American Association for Anatomy (2021) offers a comprehensive list of anatomy education programs on their website. Such programs produce a cadre of anatomy-focused educators who are equipped to meet the growing demand for qualified anatomy faculty.

While enrolled in these programs, students typically receive training in a variety of areas including the anatomical sciences (gross anatomy, embryology, histology, and neuroanatomy), educational research, qualitative and quantitative research methods, statistics, health sciences pedagogy, curriculum design, learning theory, and teaching practicums (Brokaw and O’Loughlin 2015; Walker and Ward 2007). These courses begin preparing students to fill the various roles assigned to faculty members, such as lecturer, resource developer, and
The teaching practicums allow these students the opportunity to deliver lectures, engage students in active-learning sessions, and create assessment items (Richardson-Hatcher et al. 2018). Although a teaching credential for anatomy educators has been discussed at Experimental Biology annual meetings, no credential or accreditation has been established. However, anatomists agree that pedagogy and educational research are extremely important to the development of future educators (Rizzolo and Drake 2008). Similarly, in a survey distributed by Wilson and colleagues (2020b), researchers found that departmental chairs seeking to hire anatomy educators ranked teaching experience as the most valuable experience in a candidate, followed by teaching experience in multiple anatomy disciplines and pedagogy. These courses and teaching practicums are valuable experiences that contribute to doctoral students’ training in becoming professors.

In teaching practicums students generally take on an integral role within the laboratory, while also being assigned a lecture or two to present. Their duties are focused on tasks pertaining to session implementation and examination development, proctoring, and grading. However, many students do not gain experience as a course director until they enter the realm of faculty. The term “course director” refers to individuals who design a course, develop the course syllabus and content, lead class sessions, and oversee administrative tasks (i.e. student accommodations, development of the learning management system, issuing grades). Many of the graduates from these programs will enter teaching-intensive positions upon graduating, potentially beginning their careers in a course director position. Furthermore, even fewer individuals gain experience teaching a study skills course, even though such teaching savvy would be indispensable to educators, as most instructors do not have ample time to dedicate to teaching study skills in addition to the content in a typical anatomy course.

The purpose of this phenomenological study is to describe the experience of graduate students who taught a study skills course during their time as a graduate student. This 1-credit-hour study skills course is offered at a large midwestern university to undergraduate students who are concurrently enrolled in a 200-level undergraduate anatomy course. Enrollment in the course has varied over the years, with as low as 15 students and up to 50 students enrolled in a semester. Undergraduate students are taught an array of study strategies designed to better their learning of anatomy and improve their overall study approaches. The impact of this course on student outcomes has been previously documented by one of the authors (A.S.) (Schutte 2013).

The study skills course was created by graduate students and has been offered nearly every semester for over a decade. The design of this course is unique in that is led predominately by graduate students enrolled in an anatomy education PhD program, providing them with the opportunity to run their own course as a graduate student. Over the years, the focus of the course has remained consistent; its structure is rooted in metacognition by encouraging students to examine their own learning while introducing them to research-supported study skills. These study skills are taught in the context of anatomy, and an additional goal of the course is to emphasize the transferability of these skills to other subject areas. While the theoretical framework of the course has remained the same, instructors have structured the course as they desired from semester to semester and implemented pedagogical tools based upon their personal teaching interests.

Materials and Methods

Participants

Since the study skills course was first instituted in the summer of 2010 it has been offered to students enrolled in anatomy nearly every semester. During each semester, one graduate student in the anatomy education PhD program was given the opportunity to oversee the course, taking on the responsibility of course design and instruction throughout the term. In any given year there are, on average, 8 students enrolled in this doctoral program, and the students who are given the opportunity to oversee the study skills course have already gained some teaching experience and have typically completed a fair amount of their education coursework. Graduate students are given the chance to prioritize the courses they feel qualified to teach and would like to teach, and this is factored into the decision of who will teach the course. Until the fall 2012 semester, the course was taught by one of the authors (A.S.). From the fall 2012 semester until the fall 2021 semester there were nine graduate students who each taught the course. All nine individuals were invited to participate in interviews, and eight individuals completed an interview. While most of the participants expressed a desire to teach the study skills course at some point, there were two participants who were rather unfamiliar with the course when asked to teach it. In order to support students who are typically taking on their first experience of being the instructor of record, syllabi from most semesters have been collected so they may be shared with future instructors. New instructors for the course are also encouraged to talk with past instructors to “pick their brains,” while also making the course their own. Additionally, the doctoral program director was interviewed, as they offered guidance to the graduate students who developed the course and have observed all of the graduate students as they went through the experience of teaching the course.

All participants were recruited via email. Informed consent was obtained from all participants upon scheduling their interview and reiterated at the start of their interviews. This project was approved by the UMMC Institutional Review Board (protocol #2018-0214).
Researchers
The interviewer (A.S.) is one of the co-creators of the study skills course and taught the course for several semesters prior to graduating from the anatomy education doctoral program in 2013. They were a graduate student at the same time as two of the interviewees, and, due to the close-knit nature of the anatomy education world, a professional relationship was already established (primarily through conference networking) with all of the study participants.

The existing relationship between A.S. and the participants and A.S.’s familiarity with the doctoral program, the study skills course, and the undergraduate anatomy course were viewed as assets during data collection as they allowed for the analysis team (A.S. and C.B.) to better understand jargon and program-specific references used by participants. A.S. is not presently affiliated with the anatomy education doctoral program in this study in any formal capacity besides being an alumna. C.B. is a doctoral student in an anatomy education program different from the one included in the present study. Other than brief online encounters between the two doctoral programs, they had not met any of the study participants prior to becoming involved in this study. They had no involvement with the study skills course and are unfamiliar with the specific program departmental/institutional practices about which the participants spoke.

Data collection
Semi-structured interviews were conducted as video conferences through Zoom®, and all interviews were recorded to enable transcription of the interviews. The interviewer (A.S.) conducted nine individual semi-structured interviews. Due to the nature of semi-structured interviews, the interview schedule provided a framework for each interview, while allowing the interviewer flexibility to ask questions in a different order or with modified phrasing. It also allowed the interviewer to investigate areas of interest as they emerged during the interviews that may not have been a part of the initial interview schedule. Overall, each participant was asked to discuss the following:

- current position (graduate student, faculty member, etc.)
- when and how often they taught the study skills course in their graduate career
- motivation for teaching the study skills course
- course goals and course design
- lessons learned from the experience of teaching the study skills course
- impacts of the experience of teaching the study skills course on current teaching philosophy and practices

Upon completion of the interviews, the audio recordings were transcribed verbatim to allow for thematic analysis.

Data analysis
Thematic analysis was conducted to discover themes across interviews. Thematic analysis, as outlined by Kiger and Varpio (2020), is an iterative process of analyzing qualitative data with the goal of describing and understanding shared experiences across a set of data.

This process began with both of the authors working independently to familiarize themselves with the transcribed interviews and then generate initial codes, which are simply descriptive words or short phrases used to indicate meaningful segments of text. Next, the authors discussed their individual codes to find areas of overlap and discrepancies, ultimately coming to agreement on an overall coding framework. After establishing the framework, both researchers re-coded the data with the agreed upon framework and then compared coding patterns to ensure consistency in the application of codes. Coded statements were then extracted and examined for the generation of themes. A theme is built from the comparing, combining and mapping of how codes relate to one another. This is again an iterative process involving the researchers working independently to describe themes, and then discussing themes together to assess and reach agreement on the themes that most clearly describe the relationships among the codes.

Upon establishing themes, the authors sought to engage the participants in member checking, which is a common procedure in qualitative research that allows participants in a study to review the researcher findings and offer additional input if they see fit. All interviewees were provided with a draft of this manuscript via email and provided with ample time to review and respond to indicate agreement/disagreement and provide any supplementary contributions. One of the nine interviewees responded and offered suggested changes; three other interviewees responded with no suggested changes.

Results
At the time of their interview, three participants were faculty at the instructor or assistant professor level, and five participants were graduate students. Currently, a total of five participants have completed their doctorates and are currently faculty members at either medical or undergraduate institutions in the United States. The remaining three participants are still graduate students; two are enrolled in the anatomy education PhD program and one, who received their Master’s in anatomy, is an anthropology PhD student.

Half of the participants taught the study skills course twice, although the participants taught the study skills course anywhere from one to six semesters. As participants described their experiences and the various impacts of being a course director for the study skills course, four primary
themes were discovered during the analysis: autonomy, flexibility, student-centered, and broader pedagogical impacts. Additionally, the interview with the doctoral program director was useful for reinforcing these themes, as well as shedding light on other facets of the study skills course.

Theme 1: Autonomy
The role of course director allowed the participants freedom to determine the structure of the course and activities to be implemented in the course based on their own pedagogical interests. By the time they were given the opportunity to direct the study skills course, the participants had completed some or all of their education-focused coursework which covered learning theories and pedagogical approaches. While at least some of past semesters’ syllabi were typically shared with a new instructor of record, these were meant to serve as guidance for course development rather than dictating rigid structure required each semester. The opportunity to teach this course provided study participants with the opportunity to explore teaching methods they may not otherwise be in the position to implement in their other teaching assignments. This statement by Subject 4 was reiterated by most other participants in similar manners, “I feel like you don’t get that much in the other classes we teach. We don’t have much freedom in those. I think this class allowed the freedom to say, ‘Let’s try stuff out,’ you know.”

Beyond course structure and content, these individuals were also responsible for administrative duties. While the participants, overall, did not discuss these aspects frequently, the program director described teachable moments with the graduate students who were setting up the course within the institution’s online learning management system (LMS) or navigating procedures when a student had disability accommodations. As the course director, participants also found themselves making a myriad of decisions regarding the overall course and individual students’ circumstances that they had not previously had to deal with directly as a teaching assistant (TA). Additionally, the program director described consistently seeing students become more confident after being the instructor of record for the study skills course, and that the graduate students gained a fair amount of skill and confidence from the experience. They stated, “They move away from that fixed mindset of teaching is an art or talent, and a growth mindset of, oh, I’m learning some skills and I can become better.”

Theme 2: Flexibility
While a commonly expressed sentiment was the desire to have autonomy, with such independence also came a need to be flexible at multiple levels of course implementation. Participants were ready to try approaches they had learned about in their courses and were faced with the logistical challenges that can occur with teaching. Subject 6 described building inherent flexibility into the syllabus from the start and still needing to adjust once the course started. “I’ve had to walk some of it back, because I get—I’ve gotten a lot of people not turning in assignments.”

Seemingly basic skills, such as effectively navigating the LMS required more instruction than previously assumed by the instructor. Within an individual session, participants recalled how, if they recognized a particular activity was not working for the students, they would adjust accordingly within that class session or prepare to handle the activity differently in the future. Subject 3 described, “…there have definitely been days where I was trying out something new, um, and the students were not responding at all. And so maybe I quit halfway through the class and changed it up or maybe I realized that for when I taught it again maybe the next semester.” Similarly, in discussing the attempts to have students in the study skills course draw as a method for learning, Subject 1 described the students’ resistance to the activity and how they were able to adapt their teaching approach to meet the students where they were. “…it surprised me how hard that resistance [to drawing] was to overcome.” They go on to describe how an assignment in which students were to write out the content (versus draw it) was still a viable option that was more approachable for some students.

As instructors around the world have had to do since the spring of 2020, the participants who have been leading the study skills course most recently have had to convert a class traditionally delivered face-to-face to an online format due to the COVID-19 pandemic. This radical and sudden shift in course format required additional flexibility on behalf of the course directors as they modified assignments and interactions with students. Additionally, they have had to adjust their own preferences regarding the students’ use of technology in the course. Subject 7 described a need to be flexible to accommodate student preferences for online resources versus hand-written approaches to develop study tools once the study skills course moved to an online format. The added layer of students all using different types of devices created a need for flexibility that continues to be present. As Subject 7 said, “trying to get formats that everybody can access, things that they can turn in, that I can access, that’s remained a generalized problem.” Learning to engage students in an online environment has required flexibility again, as instructors have to be willing to take different approaches to maintain or increase engagement. Subject 7 stated, “But just from the end of last semester to the beginning of this semester, encouraging them to have their videos on Zoom—we use Zoom—has helped. The number of people who actually speak up when their video is on has increased and then also saying that you can also put something in the chat. Like they might not want to actually yell something out, but they will, they will type it into the chat. And that’s helped.”

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**Theme 3: Student-centered**

That the focus for the course was on the students and what the students could gain from this study skills course was perhaps the most prominent thread in all of the interviews. Not only did the participants want the students to better their anatomy knowledge, but they also wanted the students to develop skills that would be transferable to other courses. The exact skills emphasized by each participant varied, although the goal was always improved learning. This sentiment shared by Subject 5 was shared by most study participants, “I wanted them to get study skills that could transfer out of [the study skills course] to other classes, but at the same time, really strengthen their anatomy content.”

The participants also shared the desire to assist struggling students. In the process of seeking to help the struggling students, the participants consistently shared that they gained a newfound awareness of what the students truly struggle with and how best to help them. The participants were quite introspective in these discussions, expressing a better understanding and appreciation for how others learn and that this was enabling them to be better teachers in future interactions. Subject 8 said, “I think it’s just really good experience to really see the vari-- you know--the variability with how students learn, understanding like where their struggles are. Because you pick up on things that, you know, other areas that of anatomy that they’re struggling with, and it really challenges you to think about what materials might help them outside of just doing office hours, or that kind of thing.” Subject 2 is now a faculty member who oversees an anatomy laboratory and said this of their experience teaching the study skills course, “I believe it did help inform me on how I talked to the students when I was back in the general anatomy lab courses and how I would talk to them about study strategies. And I would say my experience looking at teaching [study skills] and thinking about how I could help students figure this out has impacted how I now think about redoing our curriculum for anatomy.”

**Theme 4: Broader pedagogical impacts**

The impact teaching the study skills course had on these individuals went beyond the scope of this course alone. For Subject 4, in particular, teaching the study skills course changed their trajectory in the PhD program and shaped their dissertation work. Upon reflecting on how the experience of teaching the study skills course led them to their dissertation work Subject 4 stated, “It allowed me to, um, see things, think about things, that oftentimes don’t happen when you’re just teaching anatomy labs or something. You don’t sit back and really think as much about the pedagogical practices or something or how students actually learn [in the lab-based courses] … ”

Furthermore, the participants noted that their experiences in teaching the study skills course extended beyond graduate school, impacting the current teaching practices of those in faculty positions. Some individuals are planning to incorporate activities they utilized in the study skills course in their current teaching assignments, while others have already begun to do so. On a weekly basis, Subject 2 would ask students in the study skills course to answer a couple questions in which they described what they’d be learning recently in anatomy and then identify points of difficulty or confusion. They describe wanting to continue something similar in their current faculty role, “And I’ve been thinking about incorporating this into my lecture for the dental and medical students […] where I think I’ll have a slide asking them two questions: One—and I’ve been thinking about how to phrase it—I think I’m going to phrase it something like, “If your parent were to call you today and ask you, ‘What did you learn in school today?’ what would you tell them?” So what do you—what have you taken away from this lecture today? What is something that is making sense to you that you could take away and be like, “Okay, I understand that”? But question number two: “What is something that you’re still struggling with?”

Simply completing the interview process was a reminder to some participants of the value of their experience directing the study skills course. It was well-stated by Subject 1, “Well, having not thought about it from this perspective, but really enlightening in this conversation, is how much of my current teaching was influenced by that, which is pretty cool. And, um, also sort of highlighting some of the things that I should keep up with, and, you know, like old ideas that I just have, you know, forgotten about because of time and stuff that would be worth trying. So yeah, if your goal is to look at it from the instructor’s perspective, it was definitely valuable for me to teach it.”

**Discussion**

The four primary themes that emerged from the data analysis revealed the numerous ways teaching this study skills course contributed to the participants’ development as educators and how the themes connected to each other to provide a cohesive explanation of the experiences of these educators. Most of the participants sought out the experience out of a desire to have increased autonomy in their teaching roles and to aid struggling students in their efforts to achieve better academic outcomes. Being course director allowed them to implement methods and design resources based on their own teaching interests and to determine the utility of these tools in a classroom of their own.

Due to institutional factors, few graduate students have the opportunity to direct a course. The opportunity to instruct a study skills course and witness firsthand if students effectively used the study skills suggested by faculty is a unique experience. Implementing learning strategies is a learning process in itself, as there are a variety of factors that influence the success of their delivery. By teaching this course, graduate
students could use trial and error to learn about the realities of executing these strategies, and their willingness to self-reflect and adapt leads us to the flexibility theme.

These individuals became flexible in both course design and instruction as they sought to foster an effective learning environment for their students. Each interviewee expressed a willingness to adapt the course according to the students’ needs, whether it be in the middle of a class session, between iterations of the course, or because of the unforeseen circumstances created by the COVID-19 pandemic.

Despite the fact that many students and faculty were already familiar with utilizing technology at institutions across the world before the pandemic, students and faculty alike had to adapt quickly as the role of technology became critical in the transition to virtual learning (Guppy et al. 2021). In addition, respondents noted that this experience helped them become more student-centered, informing them about how they interacted with students. These interactions taught the participants to listen to their students to determine what study skills they valued and what study skills they were not utilizing as often, helping them further adapt to their students’ needs. These attributes have been previously documented as being beneficial to one’s teaching (Hortsch 2019).

This shift from teacher-centered to student-centered is not unique to the anatomical sciences, but rather has become an international trend in education (Scheurs and Dumbraveau 2014). Enhancing their abilities to work with students will, no doubt, benefit them as they pursue faculty positions as anatomy educators, and the broader range of skills developed from this experience are important facets of being an educator in higher education.

Harden and Crosby (2000) described six key areas of activity for medical educators: the teacher as information provider, role model, facilitator, assessor, planner, and resource developer. In the participants’ more typical teaching positions in lab-based courses they were typically facilitators or information providers, and to some extent carrying out the activities of role models. While course director for the study skills course, they took on planning, resource development, and assessor roles in addition to their other responsibilities. Developing the skills associated with these roles is important, as graduates from anatomy education doctoral programs are typically hired into faculty positions upon graduation (Brokaw and O’Loughlin 2015; Walker and Ward 2007). Each of the participants who had already begun a faculty position was involved with teaching multiple student populations, and it seems reasonable to suggest that having even a small foundation of skills developed for the array of roles an educator fills is serving recent graduates well as they transition into faculty members.

Across disciplines, graduate students are often utilized as TAs while pursuing their degrees. The participants in this study are unique as they completed coursework in education prior to becoming course directors for the study skills course. However, graduate students in other programs and institutions receive varying levels of training prior to taking on the role of TA, with it often being quite limited.

Throughout the years, research-trained faculty have experienced apprehension regarding their students’ time spent researching and teaching, as these faculty felt that their students may exhibit reduced productivity in their research endeavors if more of their time was allocated to teaching responsibilities. However, research suggests that time invested in educational training for graduate students does not negatively impact students’ research endeavors, but rather may serve to better prepare them for future faculty positions (Shortlidge and Eddy 2018). Several studies have shown that being a TA resulted in increased self-efficacy, increased confidence, and reduced communication apprehension (Mueller et al. 1997; Prieto and Meyers 1999), and that a positive correlation exists between a students’ amount of TA experience and their sense of self-efficacy in effective teaching behaviors (Boman 2013).

TA training sessions may take place in the form of orientations, workshops, or bootcamps lasting anywhere from one hour to several weeks or semester to year-long courses (Bauer and Tanner 1994; Feldon et al. 2017; Gardner and Jones 2011; Piccinin et al. 1993). Despite the fact that students may perceive short-term educational training as beneficial, this training may fall short in adequately preparing these individuals for future faculty positions (Gardner and Jones 2011). These training experiences should be viewed as the start to educational training (Tanner and Allen 2006) and more time needs to be invested in training graduate students in educational practices (Feldon et al. 2017).

The TA experience may be valuable for developing educators (Park 2004), and the results of this study suggest that the value in directing a study skills course seems to far exceed that of a typical teaching assistantship. During the graduate school experience, doctoral students begin to evolve and change (Gravett 2021), and, while graduate school begins the process of socializing students to faculty roles (Gardner 2007; Piccinin et al. 1993), it may not introduce students to all the roles expected of a faculty member (Schaefer et al. 2019). Many professors have difficulty adjusting to their new roles as faculty because graduate school failed to adequately prepare them for the various responsibilities assigned to them (Mueller et al. 1997) and new faculty are often unaware of the roles expected of them beyond teaching and research (Austin 2002).
Conclusion
The results of this study suggest that being a course director for a study skills class positively impacted the interviewees’ development as educators. While the students enrolled in this program receive formal training in learning theory and pedagogy, we conclude that individuals who lack formal training in learning theory and pedagogy would also benefit from a similar opportunity. If course directorship is not an option at an institution, we recommend allowing the student to take on more administrative and teaching responsibilities within a course. Providing students with experiences more authentic to and indicative of the various roles expected of faculty will better prepare them to become future faculty members. To help facilitate the transition from graduate student to faculty member, we suggest offering graduate students opportunities to be more autonomous whenever possible.

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About the Authors
Casey Boothe is a doctoral student in the PhD in Clinical Anatomy Program at the University of Mississippi Medical Center. Her dissertation research focuses on the study strategies, time management, and metacognitive skills of master’s students enrolled in graduate anatomy courses. She is a new member of HAPS. Dr. Audra Schaefer earned her PhD from Indiana University in Anatomy and Cell Biology in 2013. She is currently the assistant director of the Clinical Anatomy PhD program and teaches medical neurobiology and histology at the University of Mississippi Medical Center. Her research interests include metacognition, study strategies, and training of educators. Dr. Schaefer has been a member of HAPS since 2009.

Literature Cited


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The Relationship Between Success in A&P and Completing an Early Online Academic Orientation

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Abstract
The current study examines if participants completing an early online academic orientation display significantly higher levels of achievement in anatomy and physiology (A&P) compared to those who do not complete this orientation. The study involves a sample of first year nursing students in a private Catholic college in a major midwestern city in the United States. A bivariate model indicates that success in A&P is significantly associated with composite test of essential academic skills scores (TEAS scores) and composite ACT scores. The bivariate model reflects those students who attend an early online academic orientation have significantly higher levels of achievement in an A&P course relative to those that do not. Future research may benefit from a mixed-methods design that might include a qualitative piece incorporating student perspectives regarding why attending an early academic orientation might be associated with higher achievement outcomes in A&P relative to those who do not attend such an orientation. http://doi.org/10.21692/haps.2022.004

Key words: achievement, academic orientation, anatomy and physiology

Introduction
Student success in anatomy and physiology (A&P) is an important research topic in nursing education. Success in A&P is a predictor for future success in nursing courses. The literature suggests that student success may be predicted by several factors, including standardized test scores (Harris et al. 2013; Schutte 2015), writing competency (Anderton et al. 2016), and participation in science coursework at the secondary education level (Vitali et al. 2020). However, level of success in A&P has not been substantially examined in relation to the presence or absence of early online academic orientation prior to beginning a college A&P course. The current study examined how achievement in a first semester A&P course differed among students who attended an early online academic orientation, compared to students who did not.

The literature links student success in A&P to several different factors. Student achievement may be predicted through participant high school GPA (Gultice et al. 2015). However, there are other notable factors. Anderton and colleagues (2016) observed that success may be correlated with student writing competence, although a similar relationship was not observed in terms of student reading ability. In terms of standardized testing, Schutte (2015) found that students who remediated A&P had lower SAT verbal and math scores than non-remediating students. In a study of nursing education attrition, Harris and colleagues (2013) noted that over half of unsuccessful nursing students had ACT scores lower than the national average and that 72% had repeated A&P coursework. While identifying other factors, Vitali and coworkers (2020) suggested that exposure to science courses in high school was a determinant for student success in A&P at the college level. Additional considerations included a student’s adaptability, emotional intelligence, and the mode of course delivery.

In nursing education, the impact of student success in A&P is monumental. The link between student grades in A&P and student performance on professional licensure exams has been documented since the 1980s (Quick et al.1985). In the 1990s, researchers linked A&P knowledge to success in a subsequent clinical nursing course (Griffiths et al. 1995). In a 2015 review of the literature, Sears and colleagues captured the ongoing, persistent nature of the relationship between student performance in A&P and success, especially regarding licensure exams. The research suggests that interventions to promote student success in A&P may be a promising tool to support long reaching student success.

With respect to improving student performance in A&P, research suggests that student preparation through orientation may factor into academic success. Traditionally, student orientation to college, including study skills and advising information, has been identified as playing a pivotal role in student retention (Davig and Spain 2003). The ongoing work of McKenna et al. (2018) further suggests that student orientation is associated with significantly higher end-of-term grades. Additional investigations suggest that the development of an academic mindset, characterized by a sense of self-efficacy, is specifically associated with student success (Han et al. 2017).
Because A&P is frequently a gateway course for future studies in health sciences, success in its coursework largely determines a student’s educational trajectory. The current study assessed the impact of academic orientation as a tool for promoting academic success in A&P. In this case, academic orientation was distinguished as a process that was distinct from generalized student orientation. Here, the term “academic orientation” refers to content that addresses topics which include college-level learning content, college learning management systems, and any innovative cloud-based technologies and courseware that are integrated into the college learning management systems. The study examined whether students who attend an early online academic orientation have a significantly higher level of success in A&P relative to students who do not attend an early online academic orientation.

The analysis included several variables that were predictors of success in A&P, such as composite ACT scores and composite test of essential academic skills (composite TEAS scores). The analysis represented an early attempt to identify best practices in orientation for student success in A&P. Preliminary data suggested that the positive impact of college orientation may be determined by orientation content. The early academic orientation modules students utilized in this study were in cloud-based courseware that was deeply integrated into their college learning management system.

Three competency-based learning modules were developed for the early online academic orientation. The modules were approximately two hours each and covered the fundamentals of biology, fundamentals of chemistry, and fundamentals of scientific skills. Teaching strategies used in these early online academic orientation modules included active learning as the core pedagogy and relied on activating information from existing knowledge. Students were encouraged to organize their thoughts through sketches and or in note taking apps. Learning objectives were provided as short answer questions at the end of each module, to enhance student understanding of the material they would be expected to understand. Instant feedback was given to each of the short answer learning objectives, so the students could self-identify and build in their metacognition.

Module 1 included an introductory biology overview. Cell structure: cell metabolism, cellular transport, cell division, DNA, nucleic acid structure, DNA replication, and gene expression were covered in this module. Module 2 included an introductory chemistry of life overview. Content for this module included atoms, molecules, chemical bonding, acids and bases, and major macromolecules. Module 3 included an overview of scientific skills. Content for this module included graphing and interpretation, fundamentals of math, understanding exponents, units of measurement, and dimensional analysis. Collectively it took students between six to nine hours to complete all three modules.

The early online academic modules were originally placed in the LMS prior to the arrival of students on the first day of class. The early online academic orientation modules were open from the time of their general college orientation (June and/or July) through the second week of the fall semester course (August). The three early online academic orientation modules collectively were assigned the same number of points as one quiz assignment. Students in this course were allowed to drop their lowest quiz grade; if they did not complete the early online orientation, it did not academically penalize them.

Methods

At a private single-purpose nursing college composed of primarily female (86%) nursing students, all entering first-year undergraduate students were provided with a general college orientation that equipped them with resources to understand policy and to find support. Of the 94 students enrolled in the first semester of a two-semester A&P course, 82 chose to enroll in the additional online academic orientation (the “treatment”). The remaining 12 students served as the control group.

As this is a quasi-experimental design for evaluation of the effectiveness of the online academic orientation, non-random assignment of study participants to either “treatment” or “control” was important for ethical reasons so that all students had equal opportunity to complete the orientation. Data gleaned from the orientation process has been shared under the supervision of the Institutional Review Board, which approved analysis and dissemination.

In terms of standardized test results, the scores of the 94 students were evenly dispersed among attendees and non-attendees. The institution uses TEAS (Test of Essential Academic Skills) to assess student placement. The TEAS is an exam that helps assess if a student has the necessary knowledge and comprehension to enter a nursing college or other related allied health field. The company that forms the test is Assessment Technologies Inc. (ATI). Of the entering students, 43.6% (n=41) scored at a basic level for their incoming academic skills, while 51.1% (n=48) scored at a proficient level and 5.3% (n=5) scored at an advanced level for their incoming academic skills. The average study participant enrolled with an ACT composite score of approximately 21.4 (M = 21.4; SD:2.95; Min/Max 16.00/29.00).

Previous analyses on data from 713 first time-in-college (FTIC) students who took this first semester A&P I course during an eleven-year period, provide foundational comparison of the study participants’ incoming academic preparation. While this large group of students could serve as a potential control group in future studies if the 82 students who opted into the academic orientation are removed, this study utilizes the non-attendees within the single cohort as a control group. Testing for equal variance was conducted, as will be discussed in the continued on next page
The Relationship Between Success in A&P and Completing an Early Online Academic Orientation

The purpose of this comparison group is to illustrate that the study participants have similar academic levels to those of surrounding years, thus increasing the generalizability of the data. Using this larger group of students, exploratory multivariable analyses were also conducted to verify the correlations identified within the study participants, as will be discussed in the data analysis. In the larger group of students, the average TEAS score was 60%. A TEAS score of 60% is close to the national average and would classify a student as “Proficient” by ATI. This same comparison group had an average ACT composite score of 22, and an average high school GPA of 3.57. High school GPA, TEAS composite scores, and ACT composite scores were similar in both the larger group of 713 students and the study population of 94 students.

The same Associate Professor of Biological Sciences has taught this A&P course for the past two decades. The professor used the same textbook, courseware, tests, and student learning objectives for all students in the experimental study (94) and for the larger comparison group.

Measurement Instruments
A short scale examining study demographics (e.g., TEAS composite scores and ACT composite scores) was created for the current study. Completion of early online academic orientation modules was measured with a single item Have you completed the early online academic orientation modules? (Yes/No). The construct success in A&P was measured using a 5-item scale created for the current study. Grades were measured along a scale of 1 (Grade of F) to 5 (Grade of A).

Data Analysis
Data analysis was conducted in three phases. First, all data were analyzed descriptively utilizing univariate analysis. Second, the relationship between the dependent variable success in A&P with the independent (did you complete the early online academic orientation modules?) and covariate (composite TEAS, composite ACT) variables were analyzed using bivariate analysis. Third, multivariable regression analysis was performed to control for other demographic and academic preparedness variables while examining the relationship between A&P grades and completion of the academic orientation.

Prior to data analysis was an examination of test assumptions indicating satisfactory levels for multicollinearity, linearity, and homoscedasticity. Based on a G* Power estimate of multiple regression, with power set at 0.80 and a probability set at 0.05, a medium size effect (0.15) would be detectable using a sample size of 54. The power analysis indicated 54 students was the minimal sample size required to detect a relationship between the three variables (TEAS composite, ACT composite, and the independent variable: whether or not the student completed the early online academic modules) prior to beginning their first semester of A&P at the college. Checks of data integrity were initially collected from 94 students. Five students had missing ACT composite scores, as they were adult learners and had attended high school more than 10 years prior to enrolling at the college. These five students were kept in the study. Codes were utilized during the analysis to represent the missing data while using SPSS statistical software. The final sample for the study included 94 students.

Results
Table 1 presents a descriptive analysis of the variable tracking student completion of the academic orientation. More than half of the students completed the early academic online orientation modules before beginning their first semester of A&P (n = 82, 87%). Table 2 represents a descriptive analysis of the variable success in A&P. Data indicate that the score reflecting success in A&P was 3.28 (SD 1.13; Min/Max 1.0 - 5.0).

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEAS Composite</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Basic</td>
<td>41</td>
<td>43.6%</td>
</tr>
<tr>
<td>Proficient</td>
<td>48</td>
<td>51.1%</td>
</tr>
<tr>
<td>Advanced</td>
<td>5</td>
<td>5.3%</td>
</tr>
<tr>
<td>Academic Orientation Modules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completed</td>
<td>82</td>
<td>87.2%</td>
</tr>
<tr>
<td>Did not complete</td>
<td>12</td>
<td>12.8%</td>
</tr>
</tbody>
</table>

Table 1. Descriptive Analysis of Categorical Study Variable (n = 94)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD)</th>
<th>Min/Max</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>A&amp;P I Grade</td>
<td>3.28 (1.13)</td>
<td>1.0 – 5.0</td>
<td>1.0 – 5.0</td>
</tr>
<tr>
<td>ACT Composite</td>
<td>21.4 (2.95)</td>
<td>16 – 29</td>
<td>1.0 – 36</td>
</tr>
</tbody>
</table>

Table 2. Descriptive Analysis of Continuous Study Variables (n = 94)

continued on next page
Bivariate Analysis

Table 3 presents a bivariate analysis comparing the dependent variable success in A&P to the first covariate variable: student TEAS composite scores. One-way ANOVA indicated a significant difference (F = 12.79, p < 0.001) between mean scores. A Bonferroni post hoc test indicated the mean score for success in A&P differed where: 1) The score for the TEAS composite Basic; M = -0.9385, (SD = 0.2146) was significantly lower than Advanced and Proficient composite TEAS scores; 2) The score for Proficient M = 0.9385 (SD = 0.2146) was significantly higher than Basic but lower than Advanced scores; and 3) The scores for the Advanced, M = 1.692 (SD = 0.4780) were significantly higher than Basic and Proficient Scores.

Table 4 presents a bivariate analysis of success scores and ACT scores. Student composite ACT scores and success in A&P were positively correlated at a statistically significant level (r (94) = 0.44, p < 0.01).

Multivariable Analysis

As further context for the relationship between academic preparedness and first year cumulative college GPA for BSN students at the college, separate multivariable analyses have also been conducted on freshmen from 2010 through 2020, which is inclusive of the cohort of 94 students that constituted the direct study population. For first-time college students (i.e., those having no college transfer credit) entering college during the fall, multiple regression models were constructed to evaluate the predictive values of three preparedness measures: high school grade point average, composite ACT score, and composite TEAS score. There were 913 students in the initial analysis, though only 713 had non-missing values for all variables used in the final multivariable regression model.

Prior to building the models for first-year outcomes, correlation tests were conducted to investigate the multicollinearity among the three preparedness variables. A Pearson correlation test indicated that high school GPA and composite TEAS scores were moderately correlated (r (793) = 0.44, p < 0.0001). Spearman correlation tests indicated that high school GPA and composite ACT scores were also moderately correlated (rs (887) = 0.36, p < 0.0001), and TEAS scores and ACT scores were strongly correlated (rs (769) = 0.68, p < 0.0001).

Considering the strong correlations between TEAS and ACT scores, it was determined that only one of them should be included in a multivariable regression in order to avoid excessive multicollinearity. Two different simple linear regressions were run using each of the preparedness variables to find which measure of preparedness had the strongest predictive value of first-year college GPA. The regressions revealed that TEAS scores and ACT scores each had a weak but significant positive correlation with first-year college GPA. Compared to the ACT score, the TEAS score explained a slightly higher percentage of the variance in first-year college GPA and was significant F (1,711) = 142.0, p < 0.0001, R² = 0.17, R² adjusted = 0.17). When the TEAS score and high school GPA were both included in a regression model, 22 percent of the variance in first-year college GPA was accounted for by the variables in the model (F (2,710) = 101.4, p < 0.0001, R² = 0.22, R² adjusted = 0.22). Using forward selection step-wise regression with the demographic variables gender, ethnicity, and campus coded as dichotomous variables (female = 1, male/unknown = 0; Black, Indigenous, or Person of Color (BIPOC) = 1, White/unknown = 0; enrolled at regional campus = 1, main campus = 0), a significant multivariable regression model emerged with gender and campus included along with TEAS score and high school GPA as predictors of first-year college GPA (F (4,708) = 53.83, p < 0.0001, R² = 0.23, R² adjusted = 0.23). A significant multivariable regression model was built with the following independent variables explaining about 33 percent of the variance in final A&P grades: high school GPA,
The Relationship Between Success in A&P and Completing an Early Online Academic Orientation

TEAS score, gender, campus, and ethnicity (F (5,180) = 18.96, p < 0.0001, R² = 0.35, R² adjusted = 0.33). In this model, the TEAS score, high school GPA, and ethnicity (identifying as BIPOC) were all significant predictors of a student's A&P grade at α = 0.05. Table 5 presents the full results from this multivariable regression.

This multivariable regression using 11 years of student data in a highly consistent A&P course serves as an important backdrop to further investigation of the original study population (the 94 students who were given the option to attend an early online academic orientation). Using multivariable regression on this subset of students, statistical controls were employed to ascertain whether any of the demographic or academic preparedness factors explored in the previous regression models were primarily responsible for the improved A&P grades among students who attended the academic orientation, or if A&P grades were predicted by attending the early online academic orientation.

To specifically assess the explanatory power of attending the online academic orientation on A&P grade when controlling for TEAS score, high school GPA, ethnicity, and gender, a multivariable regression model was constructed for the students with non-missing values for their final A&P grade (i.e., students with a letter grade A-F, excluding incompletes and withdrawals) and non-missing values for all other variables in the model. The final subset with non-missing values included 63 students, with 52 who attended the academic orientation and eleven who did not. Regional campus attendance was not included in this model because the cohort offered the early academic orientation were all enrolled at the institution's main campus.

Prior to building this model using the reduced subset of sixty-three students, a two-sample t-test was performed to recheck the difference in mean A&P grades between the orientation attendees and the non-attendees. An F-test to check equality of variance between the two groups was not significant, confirming that variances were equal, and testing could proceed. There was a significant difference in mean A&P grades (t (64) = -5.02, p < 0.0001) with orientation attendees having a higher average. Having confirmed the significant difference in average grades and the equal variance between the control and treatment groups within this subset, the regression model was an appropriate next step.

The model was statistically significant with the predictors explaining 39% of the variance (F (5,57) = 8.88, p < 0.0001, R² = 0.44, R² adjusted = 0.39). In this model, attending the academic orientation was a highly significant predictor of a student’s A&P grade (p = 0.0001) with a positive slope. TEAS score and high school GPA were also significant predictors in a positive direction.

When comparing standardized beta coefficients of the three significant independent variables (attendance at academic orientation, TEAS score, and high school GPA), attending the academic orientation had the strongest effect on a student’s A&P grade, as seen in Table 6. This result supports the findings of the descriptive and bivariate analyses and indicates that attendance at the academic orientation predicted a significantly higher grade in A&P compared to those who did not attend, even when controlling for demographic and academic preparedness variables.

<table>
<thead>
<tr>
<th>Effect</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEAS Score</td>
<td>6.09</td>
<td>0.80</td>
<td>0.52</td>
<td>7.58</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>High School GPA</td>
<td>0.46</td>
<td>0.21</td>
<td>0.15</td>
<td>2.24</td>
<td>0.026</td>
</tr>
<tr>
<td>BIPOC</td>
<td>0.40</td>
<td>0.17</td>
<td>0.15</td>
<td>2.38</td>
<td>0.018</td>
</tr>
<tr>
<td>Female</td>
<td>0.08</td>
<td>0.29</td>
<td>0.02</td>
<td>0.29</td>
<td>0.775</td>
</tr>
<tr>
<td>Regional Campus</td>
<td>-0.37</td>
<td>0.26</td>
<td>-0.09</td>
<td>-1.43</td>
<td>0.154</td>
</tr>
</tbody>
</table>

**Table 5. A&P Grade: Multiple Regression (n=186). B = unstandardized beta, SE B = standard error for the unstandardized beta, β = standardized beta.**

<table>
<thead>
<tr>
<th>Effect</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEAS Score</td>
<td>1.99</td>
<td>0.82</td>
<td>0.25</td>
<td>2.44</td>
<td>0.018</td>
</tr>
<tr>
<td>High School GPA</td>
<td>0.73</td>
<td>0.25</td>
<td>0.30</td>
<td>2.96</td>
<td>0.005</td>
</tr>
<tr>
<td>BIPOC</td>
<td>0.17</td>
<td>0.22</td>
<td>0.08</td>
<td>0.74</td>
<td>0.460</td>
</tr>
<tr>
<td>Female</td>
<td>0.14</td>
<td>0.42</td>
<td>0.04</td>
<td>0.34</td>
<td>0.738</td>
</tr>
<tr>
<td>Attended Academic</td>
<td>1.28</td>
<td>0.31</td>
<td>0.45</td>
<td>4.13</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

**Table 6. A&P Grade: Multiple Regression (n=62). B = unstandardized beta, SE B = standard error for the unstandardized beta, β = standardized beta.**
Discussion

The findings of this study support the hypotheses that first semester A&P students who complete an early online academic orientation have significantly higher levels of success in A&P relative to those who do not. The analysis also suggests additional factors correlated with A&P grades include ACT score, TEAS score, high school GPA and, possibly, ethnicity.

While these findings support the development and implementation of a robust early online academic orientation for entering students, the findings also identify factors related to student success which extend beyond the reach of college educators. Student preparation for success in higher education begins well before college admission.

Limitations

The findings of the study are limited by the scope of investigation. A larger project may take into consideration data collected throughout a student’s college career. Because enrollment in academic orientation was voluntary, it must be acknowledged that students who opted into such a program may be predisposed towards academic success. However, it is also possible that some students enrolling in the orientation program are less confident in their academic skills and have reason to believe, perhaps due to prior experience in science courses, that they need the additional review of material. Likewise, some students with strong academic preparation may skip the orientation program because they predict they will succeed in A&P without it.

Controlling for academic preparation indicators such as TEAS and high school GPA attempts to account for these differences, but future studies could also incorporate a measure of student perception of their own abilities. Incoming students at this institution participate in a new student survey, which asks about their levels of confidence and how they perceive their academic abilities compared to “average” levels; such data could be leveraged to further control for differences in academic predispositions and attitudes.

Furthermore, deeper multivariable regression analysis should consider additional demographic characteristics that were not readily available in the institutional student database, such as income status and whether or not they are first-generation college students. Other dimensions of analysis in the future will also look specifically at the science portion of the ACT and the TEAS tests, rather than the composite score.

Another limitation of this study is the sample size for conducting comparison, since most students opted into the program, resulting in a small group of non-attendees. The relatively small number of students who remained in the final multivariable regression is a result of a combination of missing values of demographic or academic preparation variables, along with the withdrawal of some students from the course or the institution for reasons that may have nothing to do with academic difficulty. While the general rules of thumb are met for reasonable sample size for regression analysis (Voorhis and Morgan 2007), further analysis could incorporate multiple years of data to increase the sample size of non-attendees. A simple expansion could potentially use the preceding year of enrollees, where the entire earlier cohort would function as non-attendees for comparison.

Conclusion

The finding that students who completed early academic online academic orientations achieved significantly higher levels of success in A&P relative to those who did not suggests that the early online academic orientation should continue as part of the college general orientation. Student surveys were not conducted qualitatively to determine if they thought the online orientation helped them prepare for their first semester of courses. In the future, it is suggested that a qualitative study be conducted to examine if the early online orientation helped orient students to the college learning management system and the cloud-based technology they would be using in their first semester courses.

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Literature Cited


Electric Field Lines and Local-Circuit Currents Explain the Propagation of Axonal Action Potentials

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Abstract
Propagation of action potentials occurs when electric fields arise among plasma membrane regions at different electric potentials. These electric fields are visualized by electric field lines. Current will flow through conducting media (cytosol and interstitial fluid), forming a local-circuit current. These electrotonic currents flow longitudinally along the fiber. When they cross the membrane from inside out, they produce a depolarizing effect that may reach threshold on the non-stimulated membrane regions. Local-circuit currents depend on the passive properties of axons that explain why the propagation velocity of action potentials is faster when the diameter of the fiber is larger (less longitudinal electric resistance), the length constant of the fiber is longer (electrotonic currents spread farther), and the membrane capacitance is lower (threshold voltage is reached faster). The roles of the myelin sheath and the location of voltage-gated Na⁺ channels at high density on the nodes of Ranvier in increasing propagation velocity are analyzed. http://doi.org/10.21692/haps.2022.007

Key words: propagation, axonal action potentials, electric field lines, local-circuit currents, myelin sheath

Introduction
One of the most difficult tasks in teaching human physiology to sophomores seeking a major in Nursing or Allied Health Sciences is to explain these concepts based on the students’ previous knowledge. The concept of propagation of action potentials is a challenging topic for students to understand and for faculty to explain in a concise way. When considering its application for the future professions of these students, this knowledge is needed for understanding the classification of axons based on their speed of propagation, the pathophysiology of diseases produced by demyelination, and the recordings of electrocardiograms and electromyograms, among other electrograms (Sperelakis 2012). The purpose of this paper is to provide straightforward explanations and illustrative diagrams that can help instructors explain these complex concepts to their undergraduate (mostly sophomore) students.

There is only one mechanism for propagation of action potentials (APs), regardless of the type of excitable cell in which they are generated. To understand this mechanism, first one must describe what happens between two plasma membrane regions with a difference in their electrical potential (voltage). To simplify the analysis, one can assume that in one of these membrane regions the inner (cytosolic) side is charged positively (+30 mV), while the other membrane region has its inner side negatively charged (-70 mV). An electric field is thus generated between these two regions of the membrane and electric field lines provide a helpful way to visualize patterns in electric fields (Halliday et al. 2008). Electric field lines extend away from positive charge (where they originate) toward negative charge (where they terminate). The density of the electric field lines represents the intensity of the electric field with higher density of the electric field lines indicating stronger electric field intensity. The magnitude of the electric field decreases with distance (Halliday et al. 2008). Figure 1 illustrates these general physical concepts applied to the membrane of an excitable cell in which there are two regions with different electric potential at different distances between them (compare the density of the electric field lines in Figure 1A with that on Figure 1B).

Figure 1. Schematic of electric field lines and the local-circuit currents. A) Condition when two regions of a plasma membrane that are nearby have different membrane potentials. B) Condition where the two membrane regions with different membrane potentials are farther apart, the electric field between them is weaker, and a smaller density of the electric field lines reflects this.
Current will flow through a conducting medium (as that of the cytosol and the extracellular fluid [ECF]) between the two regions of the membrane of an excitable cell that is at different electric potential. These longitudinal currents flow through the cytosol from the positively charged region (current source) to the region that is negatively charged. Then they flow transversely through the cell membrane out into the ECF. Finally, these currents flow again longitudinally through the ECF from the positive region outside the membrane back to the negative region, thus, completing the closed loop for this current, named a local-circuit current (Sperelakis 2012).

As the local-circuit current is produced by an electric field, the electric charges involved in these longitudinal currents are positive and involve K⁺ in the cytosol and Na⁺ in the ECF. These are the most abundant cations in each of these conduction media. These longitudinal currents do not involve the diffusion of these ions. To emphasize this concept, consider that for K⁺ (with a diffusion constant of 10⁻⁵ cm²/s in water), 10 seconds are required to diffuse 100 µm and 16.7 min to diffuse one mm. Furthermore, Na⁺ diffuses in water considerably more slowly than does K⁺ (ratio of 1:2) (Sperelakis and Friedman 2012).

The local-circuit current that flows transversely through the plasma membrane from the cytosol to the extracellular fluid depolarizes the membrane by a capacitive current that does not involve the flow of ions through the membrane, and, consequently, may affect voltage-gated ion channels in excitable cells. Both the cytosol and the ECF are aqueous solutions, thus each one offers a longitudinal electrical resistance to the longitudinal currents described, which have been named electrotonic spread (Blaustein et al. 2012; Koester and Sieglebaum 2000). The outside longitudinal resistance in the interstitial fluid is relatively small compared with that of the cytosol because of the larger volume (cross-sectional area) of fluid available to carry the outside longitudinal current. It is, therefore, assumed to be negligible. On the other hand, the longitudinal electrical resistance of the cytosol is high and cannot be ignored (Blaustein et al. 2012; Sperelakis 2012).

Action potential propagation occurs because of local-circuit currents that depend on the passive or cable properties of excitable cells (Blaustein et al. 2012; Sperelakis 2012). These properties include the membrane resistance (Rm) and capacitance (Cm), as well as the longitudinal electrical resistance of the cytosol (Rc), the latter determined mainly by the diameter of the fiber. These passive properties are expressed as the time constant of the membrane and the length constant of the fiber. Typical values for these constants in nerve fibers are around 1.0 ms for the time constant and between one and three mm for the length constant (Sperelakis 2012).

**Explanation of the Mechanism of Propagation of Axonal Action Potentials**

The mechanism of propagation of APs in unmyelinated axons will be described first because it involves two well-studied and highly selective voltage-gated ion channels: one for Na⁺ and another for K⁺.

Figure 2 depicts four consecutive segments of an unmyelinated axonal membrane (A, B, C, D), each of which contains the two types of voltage-gated ion channels mentioned. These are present all along the axon in its conduction region. The figure depicts these segments of axonal plasma membrane at three different moments (Times 1, 2, and 3) after segment A has been stimulated with a suprathreshold depolarization generating an action potential. For simplicity of this analysis, let us consider that at Time 1 the AP in segment A is above 0 mV (overshoot region of the rising phase), so the inner side of the plasma membrane is charged positively. At Time 1, segment A is the active zone of the propagation mechanism.

**Figure 2.** Propagation of action potentials (AP) in unmyelinated axons. The figure depicts four consecutive membrane segments (A, B, C, D). As there are different membrane potentials in each of these segments at different times, there are electric fields between them, and the corresponding electric field lines depict the local-circuit currents producing the propagation. The asterisk by the letter indicates that the membrane is in the refractory period of the action potential. RMP = resting membrane potential.

...continued on next page...
At Time 1 the inactive zones that have not been stimulated are the membrane segments to the right of segment A. They have the polarity of the resting membrane potential (RMP) and, so, are negative on the inner side of the membrane (Figure 2). Thus, electric fields are established between segment A and segments B and C. These electric fields may be represented by the electric field lines of the local-circuit currents, with higher density between the nearer segments (A and B), decreasing in intensity between farther segments (A and C), and no effect between (A and D).

The explanation of the pure electrical nature of AP propagation, not involving ions diffusing longitudinally along the axoplasm, is the following. The local-circuit current flowing from inside to outside through the plasma membrane generates a depolarization. Considering the distance between the segments of membrane depicted, the local-circuit current between segments A and B generates a depolarization that is suprathreshold, while the current between segments A and C, is subthreshold. Consequently, at Time 2 the AP has already propagated by this mechanism to segment B by the electrical effect of the AP generated in segment A, the only area of the plasma membrane to be stimulated.

As the AP is already in segment B, and we assume that at Time 2 it is above 0 mV (overshoot region of the rising phase), the AP in segment A is now in its falling phase below 0 mV with the inner side of the membrane negatively charged (depicted by an asterisk (A*) in Figure 2). This interval of the action potential in segment A is part of the absolute refractory period during which the axonal membrane will not generate a second AP regardless the intensity of the depolarization applied. Thus, although between the positively charged inner side of segment B and the negatively charged inner side of the membrane in segment A the local-circuit current flows from inside out at segment A, this depolarization cannot generate a second AP in segment A because its membrane is in its refractory period (Blaustein et al. 2012; Koester and Siegelbaum 2000).

The above description explains why the propagation of action potentials always occurs from an active region (with an AP) to an inactive region with its membrane at RMP, as shown by the black horizontal arrows at the end of the axonal membrane. In Figure 2, the propagation of APs depicts occurring from left to right. Under physiological conditions, the propagation of APs is unidirectional.

The representation at Time 3 explains what is happening in segment C, where the AP is already above zero mV, while the membrane at segment D is receiving a suprathreshold depolarization by the corresponding local-circuit currents. Consequently, the next segment where the AP will generate is in segment D. Also, the interaction between segment C and segment B (the latter now in its refractory period) is the same as that previously described at Time 2 between segment B and segment A.

Continuous conduction is the name for the propagation of action potentials in an unmyelinated axon (Figure 2) and it requires the generation of an AP in each of all consecutive segments of the axonal plasma membrane. As seen in Figure 2, this does not imply that an AP must complete all its phases in each segment before the next segment of the axolemma will start to generate its AP. The surface of the plasma membrane of an unmyelinated axon involved in the generation of an AP at any given moment may be calculated by multiplying the speed of propagation by the duration of the AP (Sperelakis 2012). For example, in an unmyelinated axon where the speed of propagation is 3.0 mm/ms and the AP duration is two ms, the length of the axon simultaneously undergoing some phase of the AP is 6 mm, involving several consecutive membrane segments.

Factors Affecting the Velocity of Propagation of Action Potentials

The propagation velocity of APs is faster when the diameter of the fiber is larger, the length constant is longer, and the time constant and the membrane capacitance are smaller. These are some of the several determinants of propagation velocity of action potentials (Sperelakis 2012). Velocity of propagation of APs is also influenced by the presence of the myelin sheath. The diameter of an axon, among other factors, determines the longitudinal electrical resistance of its cytosol. Thicker axons offer less longitudinal electrical resistance than thinner ones. Consequently, in the thicker axons, the longitudinal local-circuit currents may generate suprathreshold intensity depolarizations at farther regions of the membrane with inactive segments. In axons, the larger the diameter, the faster the velocity of propagation (Figure 3).
Another factor affecting the velocity of propagation of APs in axons is the myelin sheath. Myelinated axons define white matter tracts, which together account for approximately 40% of central nervous system (CNS) volume in humans. In the peripheral nervous system (PNS), myelinated axons bundles constitute peripheral nerves linking the CNS to peripheral targets (Stassart et al. 2018). In the CNS, oligodendrocytes form the myelin sheaths, while Schwann cells form the sheaths in the PNS.

Each Schwann cell wraps between 0.5 and 2 mm of axon length with its plasma membrane, forming the internodal region, which represents more than 99% of the total length of the axon. In the internodal regions, the myelin sheath completely insulates the axonal plasma membrane from the extracellular fluid, which does not have contact with this aqueous solution. Thus, the myelin sheath decreases considerably the membrane capacitance in the internodal regions. Additionally, the density of voltage-gated Na⁺ channels is extremely low in the internodal regions (Figure 4).

Consecutive Schwann cells leave a small space between them, the nodes of Ranvier, in which the axonal plasma membrane is in direct contact with the surrounding ECF. It is at the nodes of Ranvier that the axonal plasma membrane has a very high density of voltage-gated Na⁺ channels (Figure 4) (Koester and Siegelbaum 2000; Sperelakis 2012). The specific topochemistry of the voltage-gated Na⁺ channels in myelinated axons, together with the myelin sheath in the internodal regions insulating electrically the axon plasma membrane from the ECF and decreasing considerably the membrane capacitance, result in a much faster propagation velocity in myelinated axons, as will now be explained.

The presence of the myelin sheath implies that the local-circuit currents flow much farther along the axon with a suprathreshold depolarizing effect (more than 2 mm) than they would in the absence of the myelin sheath (Figure 5). To this, one must add that the voltage-gated Na⁺ channels are at their highest density at the nodes of Ranvier. The combination of these two factors determines the generation of the APs only at the nodes of Ranvier. It is as if the AP “jumps” (saltare in Latin) from one node to the next (Figure 5), a propagation mechanism known as saltatory conduction. As the nodes of Ranvier are separated by 1 to 2 mm, saltatory conduction is much faster than the continuous conduction in unmyelinated axons. This conduction mechanism is also much more efficient from the point of view of cellular energy expenditure (Koester and Siegelbaum 2000) because the ionic currents occurring transversely through the membrane and generating the AP happen only at the nodes. Thus Na⁺-K⁺ pumps are found only at the membrane in the nodes.

**Figure 4.** Topochemistry of voltage-gated Na⁺ channels in the nodes of Ranvier versus the internodal regions of a myelinated axon.

**Figure 5.** Propagation of action potentials (AP) in myelinated axons. The figure depicts four consecutive nodes of Ranvier (A, B, C, D) and the corresponding internodal regions at three different times (Times 1, 2 and 3) after an AP is generated in node A. The asterisk by the letter indicates that the membrane is in the refractory period of the action potential. RMP = resting membrane potential.
For example, the axons of sensory proprioceptors that are thick (20 µm diameter) and myelinated have a speed of propagation of up to 120 mm/ms. Thinner (5 µm diameter) and less myelinated axons have lower speeds of propagation (for example, up to 30 mm/ms). Compare these values with the speed of propagation of around 3 mm/ms in an unmyelinated axon of 2 µm diameter (Fox 2013).

Saltatory conduction in myelinated axons does not imply that an AP must complete all its phases in each node before the next node of the axolemma will start to generate its AP (Figure 5). The number of nodes of Ranvier of a myelinated axon involved in the generation of an AP at any given moment may be calculated by multiplying the speed of propagation by the duration of the AP (Sperelakis 2012). For example, in a myelinated axon where the speed of propagation is 30 mm/ms and the AP duration is one ms, the length of the axon simultaneously undergoing some phase of the AP is 30 mm. This would involve between 15 and 60 nodes, depending on the length (usually between 0.5 and 2.0 mm) of the corresponding internodal regions (Sperelakis 2012).

Both types of axonal conduction of action potentials, continuous and saltatory, have the same electrical mechanism of propagation: by local-circuit currents (compare Figure 2 with Figure 5). In both types of axons, the ionic currents only flow perpendicularly to the axolemma, through the corresponding voltage-gated ion channels present on the axonal plasma membrane. The electrotonic currents are the ones that flow longitudinally along the axoplasm, which offers a longitudinal resistance to them, and they close this local circuit by flowing back through the aqueous solution of the ECF.

Instructors teaching human physiology could use the resources described using both text and figures for explaining the mechanism of propagation of axonal action potentials to their students. These resources will allow students to understand better the electrical nature of the propagation of axonal actions potentials, as well as some of the factors affecting propagation velocity. These factors include the axon diameter and the presence of the myelin sheath.

Acknowledgments
I express my thanks to Dr. Peter Narins, Professor of Integrative Biology and Physiology, UCLA, for insightful comments on the manuscript, to Dr. Ada Machado, Padrón Campus, Miami Dade College, for helping with the figures and commenting on the manuscript, and Dr. Julio Alvarez Gonzalez, Electrophysiologist, for discussions of the physical principles involved in the local-circuit currents. My thanks to two anonymous reviewers, whose comments helped improved the original manuscript.

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Francisco Coro (Professor) has been teaching human anatomy and physiology lecture courses at Miami Dade College since 2008. He was awarded an MDC Endowed Teaching Chair in 2014. His undergraduate students have presented 40 posters at several scientific conferences. He taught comparative animal physiology and biophysics at Havana University from 1970 until 2005. He is the author of the textbook Cell Physiology: A Biophysical Approach published in 1998 in Mexico and used in several universities in Ibero-America. His scientific research deals with bioacoustics in moths and heart rate variability in humans. He has published more than 30 papers in international scientific journals.

Literature Cited
Writing Intensive High Impact Practice along with Transparency in Learning and Teaching Promote Critical Thinking in Writing Assignments in Two Community College Science Courses

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Abstract
Writing Intensive (WR) High Impact Practice (HIP), which incorporates Transparency in Learning and Teaching (TILT), was applied to written assignments in Human Biology and Anatomy and Physiology II (A&P II) courses. As part of our study sponsored by the Association of American Colleges and Universities (AAC&U), certified AAC&U Valid Assessment of Learning in Undergraduate Education (VALUE) Institution rubric scorers assessed 100 assignments from students in two science courses for critical thinking using the critical thinking VALUE rubric. Students in A&P II, who had completed on average 75% of degree credits, had statistically significant higher distributions of critical thinking scores than those in Human Biology who will have completed on average 25% of degree credits at completion of the course. The distribution of scores between race and gender did not reveal any statistical differences. WR with TILT in written assignments promotes learning, equity and critical thinking. http://doi.org/10.21692/haps.2022.001

Key words: Case Study, Heart Failure, Transparency in Learning and Teaching, VALUE rubric, Writing Intensive, High Impact Practice

Introduction
Transparency in learning and teaching (TILT) is a technique that involves a collaboration among teachers and students about the processes of learning and the rationale for required learning activities. It involves a precise overview of an assignment including its purpose, how it relates to objectives of the course, and if it provides resources related to the topic of an assignment. This teaching approach helps level the understanding of assignments among students, making learning and achievement equitable. It began at the University of Illinois in 2009-2010.

Thousands of students in hundreds of courses and institutions in the United States have been involved in the development and assessment of the process. In 2014-2015 TILT partnered with the Association of American Colleges and Universities (AAC&U) to focus on advancing underserved students, including racial minorities, in higher education (Winkelmas 2013). Racial minorities include Black, African American, Asian, South Asian, Middle Eastern, Pacific Islander, Latinx, Chicano, Native American, and multiracial students.

The AAC&U promotes sixteen essential learning outcomes, two of which are critical thinking and creative thinking (AAC&U 2005). Critical thinking involves comprehensive research of issues, ideas, and facts before coming to a conclusion. The literature is replete with articles on the importance of teaching critical thinking in the classroom. It is vital to all students and especially students in science who are heading for a medical field that requires rational thinking (Bellaera 2021; Morris 2021). Critical thinking and science literacy are learning objectives of biology courses at Monroe Community College (MCC).

High impact practice (HIP) courses, including writing intensive (WR) and undergraduate research (UR), are established teaching and learning methods that have been proven to be effective (Finley 2011; Finley 2019; Kuh 2008). HIP structure and organizational methods have been effective in retention and completion especially for students who are considered underserved (Finley and McNair 2013). The WR HIP has been shown to be effective in enhancing undergraduate biology students’ perception and understanding of science (Brownell et al. 2013).

In this study, we used the WR HIP. Faculty at MCC who want a course designed WR must meet criteria and receive approval through MCC’s Writing Intensive Committee. It would appear...
that WR HIP and TILT processes complement each other, promoting equity in teaching and learning especially for underserved students (Finley and McNair 2013; Winkelmas 2013; 2014; Winkelmas et al. 2016).

The AAC&U VALUE (Valid Assessment of Learning in Undergraduate Education) rubric is an assessment approach developed by faculty. The VALUE Institute was established (2014-2017) by the AAC&U. VALUE rubrics have become a widely used validated standard assessment of outcomes including critical thinking across the United States (AAC&U 2009).

MCC was one of 20 community colleges selected by the AAC&U to participate in a competitive study grant, Strengthening Guided Pathways and Career Success by Ensuring Students Are Learning (https://www.aacu.org/strengthening-guided-pathways). MCC’s research team developed a protocol for the grant. Our study determined whether integrating the WR HIP with TILT in science assignments, which incorporates topics taught in class, has clear instructions and prompts critical thinking in a beginning level Human Biology course and a progressive enhancement of critical thinking in an upper-level Anatomy and Physiology II (A&P II) course as assessed by the VALUE rubric.

**Methods**

The study was conducted during the Spring 2020 semester. Seven sections of Human Biology taught by seven full-time faculty and two sections of A&P II taught by two full-time faculty were involved in the study. The curricula of courses in the study had to be modified to meet WR criteria. Not all sections of Human Biology or A&P II are designated WR and only sections of courses designated WR (designed to meet MCC WR criteria) were included in this study.

Research faculty worked together to develop the same assignments. This ensured that assignments used by all sections of Human Biology and the two A&P II classes, respectively, were the same. Student criteria for entry into the study was enrollment in a Human Biology or an A&P II course and that they were in a Health Science program. A total of 100 Health Science students from Human Biology and A&P II participated in this project.

A&P II is a gateway course for many health careers, and most students taking A&P II are in a Health Science program and have completed, on average, 75% of the credits toward their degree. Human Biology is an entry level biology course for science and non-science students. Students finishing Human Biology will have completed, on average, 25% of credits toward their associate degree. A few students in Human Biology are in the Health Sciences program and take this course prior to taking Anatomy and Physiology, but this is not a requirement. As a result, we had to include seven different sections of Human Biology in the study to enroll the required number of 50 Health Science students from this course. Faculty identified eligible students with the help of MCC’s Department of Institutional Research and students were enrolled by random selection. However, there was not a large excess of eligible students in Human Biology or A&P II.

Monroe Community College’s Institutional Review Board reviewed and approved this study. It was considered minimal risk with the only risk being disclosure of student names and the design of the study prevented this. It was placed in the exempt category by MCC’s Institutional Review Board.

As part of the study design and WR course criteria, each student was given a written assignment, allowing a total of 100 assignments to be collected. We provided Human Biology students with an assignment at the beginning level of the scientific critical thinking process. Students could choose from two possible writing assignments that were based on a current issues topic: “Head Trauma in Young Athletes” or “Drug Abuse Among Athletes” (Johnson 2017). The Human Biology assignments were shorter and considered less difficult than the assignment for the A&P II students. Human Biology students based their paper on the current issues topic, textbook, lectures, laboratories, and the case study about the cardiovascular assignment.

**Student Instructions**

In creating the assignment, we used the TILT method (Winkelmas 2013, Winkelmas 2014; Winkelmas et al. 2016). We provided clear instructions and criteria as guidance for success on the assignment. Instructions included:

- A statement of the assignment goals which are to stimulate analytical, critical, and reflective thinking, develop scientific literacy, and improve understanding of concepts in biology
- Formatting guidelines for word processing, including font and margins
- Length of the submission (7 to 10 pages for the A&P assignment and 3 to 5 pages for the Human Biology assignment)
- Due date
- Grade points for the assignment as an incentive
- Prompts of topics/issues to cover in the paper
- Sources to be used as references and the method for citing sources
- List of examples on how to format references from different sources
- Copy of the AAC&U critical thinking rubric
Case-Study

The cardiovascular case study was slightly modified by adding TILT methodology. In order to complete the case-study assignment, students needed to have an understanding of the anatomy and physiology of the heart, mean arterial pressure (MAP), factors that affect MAP, cardiac output and total peripheral resistance. Students needed to understand the hormones which regulate blood volume: the renin-angiotensin-aldosterone-system (RAAS), antidiuretic hormone (vasopressin), atrial natriuretic peptide and brain (ventricular) natriuretic peptide. They also needed a basic understanding of heart failure. The case-study provides a brief description of the above anatomic and physiologic cardiovascular terms, conditions, and heart failure, multiple resources including images, as well as video and written references for students to research in order to learn more.

Based on what students have read and learned in class, laboratory, and references, they were required to write a 7-to-10-page paper. A list of TILT prompts were added to the case-study to help students write the paper such as: describe mean arterial pressure and its importance, describe the factors that influence MAP and how they achieve this, identify hormones affecting blood volume and explain their pathways and how they achieve these changes, explain the factors that are contributing to Mark’s heart failure, explain why Mark has edema around the lungs and throughout the body, address the question of whether or not the fact Mark is an African American could have an influence on his heart failure.

Critical Thinking Rubric

Each of the 100 assignments was assessed for critical thinking by the AAC&U Value Rubric Institute. External scorers, who were trained and certified by the AAC&U, evaluated five categories of critical thinking: explanation of issues, evidence, influence of context and assumptions, student’s position (perspective, thesis/hypothesis), and conclusions (implications and consequences) using the rubric (Table 1).

At the completion of the study, we sent to AAC&U the 100 assignments and an Excel metafile. The assignments and Excel

<table>
<thead>
<tr>
<th>Category</th>
<th>Capstone</th>
<th>Milestones</th>
<th>Benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation of issues</td>
<td>Issue/problem to be considered critically is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding.</td>
<td>Issue/problem to be considered critically is stated, described, and clarified so that understanding is not seriously impeded by omissions.</td>
<td>Issue/problem to be considered critically is stated but description leaves some terms undefined, ambiguities unexplored, boundaries undetermined, and/or backgrounds unknown.</td>
</tr>
<tr>
<td>Evidence Selecting and using information to investigate a point of view or conclusion</td>
<td>Information is taken from source(s) with enough interpretation/evaluation to develop a comprehensive analysis or synthesis. Viewpoints of experts are questioned thoroughly.</td>
<td>Information is taken from source(s) with enough interpretation/evaluation to develop a coherent analysis or synthesis. Viewpoints of experts are subject to questioning.</td>
<td>Information is taken from source(s) without any interpretation/evaluation. Viewpoints of experts are taken as fact, without question.</td>
</tr>
<tr>
<td>Influence of context and assumptions</td>
<td>Thoroughly systematically and methodically analyzes own and others’ assumptions and carefully evaluates the relevance of contexts when presenting a position.</td>
<td>Identifies own and others’ assumptions and several relevant contexts when presenting a position.</td>
<td>Questions some assumptions. Identifies several relevant contexts when presenting a position. May be more aware of others’ assumptions than one’s own (or vice versa).</td>
</tr>
<tr>
<td>Student’s position (perspective, thesis/hypothesis)</td>
<td>Specific position (perspective, thesis/hypothesis) is imaginative, taking into account the complexities of an issue. Limits of position (perspective, thesis/hypothesis) are acknowledged. Others’ points of view are synthesized within position (perspective, Thesis/hypothesis).</td>
<td>Specific position (perspective, thesis/hypothesis) takes into account the complexities of an issue. Others’ points of view are acknowledged within position (perspective, thesis/hypothesis).</td>
<td>Specific position (perspective, thesis/hypothesis) acknowledges different sides of an issue.</td>
</tr>
<tr>
<td>Conclusions and related outcomes (implications and consequences)</td>
<td>Conclusions and related outcomes (consequences and implications) are logical and reflect student’s informed evaluation and ability to place evidence and perspectives discussed in priority order.</td>
<td>Conclusion is logically tied to a range of information, including opposing viewpoints; related outcomes (consequences and implications) are identified clearly.</td>
<td>Conclusion is logically tied to information (because information is chosen to fit the desired conclusion); some related outcomes (consequences and implications) are identified clearly.</td>
</tr>
</tbody>
</table>

Table 1. Critical thinking rubric (Association of American Colleges and Universities 2009).
Writing Intensive High Impact Practice along with Transparency in Learning and Teaching Promote Critical Thinking in Writing Assignments in Two Community College Science Courses

metafile substituted student names with ID codes. Student personal and education records are stored in MCC’s Office of Institutional Research. We sent the AAC&U student data to help generate a multiple faceted assessment report. These included information on student gender and race to help determine whether these variables had an influence on critical thinking outcomes.

Results were expressed using descriptive statistics including raw data, tables, and percentages. We analyzed the probability of a relationship between critical thinking data using Chi Square with a cut off $p$ value of 0.05.

This study was performed during the Spring 2020 semester. The COVID-19 pandemic closed the school on March 18, 2020, and education moved from face-to-face to remote.

The conversion was a challenge that involved technical training and support to get us through to the end of the semester. Education, especially labs, were affected. However, the performance of this study did not appear to be affected. Instructions for study assignments were in the course information sheet given to students at the beginning of the semester, lecture and lab information on the assignment topic were covered prior to the move to remote teaching and learning, faculty remained accessible to students concerning assignments before and during remote teaching, and students and faculty did not feel that remote teaching/learning affected their performance on the assignment.

In this article, we refer to Black, African American, Asian, South Asian, Middle Eastern, Pacific Islander, Latinx, Chicano, Native American, and multiracial as racial minority students. White students are in a separate category. Thirty eight percent of students at MCC are minority students.

**Results**

Tables 2 & 3 reveal the distribution of results for each critical thinking category for Human Biology and A&P II students. A&P II students had a significant ($p < 0.05$) higher distribution of critical thinking scores than Human Biology students for each category. Table 4 reveals $p$ values of the probable relationship between Human Biology and A&P II students for each category of critical thinking rubric results. The mean grade point average (GPA) for A&P students was 3.3 while that for Human Biology students was 2.8.

<table>
<thead>
<tr>
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<th>No Evidence</th>
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<td></td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Explanation of Issues</td>
<td>1 (2%)</td>
<td>28 (56%)</td>
<td>19 (38%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Evidence</td>
<td>0</td>
<td>5 (10%)</td>
<td>22 (44%)</td>
<td>20 (40%)</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>0</td>
<td>7 (14%)</td>
<td>27 (54%)</td>
<td>14 (28%)</td>
</tr>
<tr>
<td>Student’s Position</td>
<td>0</td>
<td>7 (14%)</td>
<td>21 (42%)</td>
<td>12 (24%)</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0</td>
<td>2 (4%)</td>
<td>31 (62%)</td>
<td>13 (26%)</td>
</tr>
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</table>

**Table 2. Critical thinking results for Human Biology students (N=50)**

<table>
<thead>
<tr>
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<th>Milestones</th>
<th>Benchmark</th>
<th>No Evidence</th>
</tr>
</thead>
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<tr>
<td></td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Explanation of Issues</td>
<td>12 (24%)</td>
<td>32 (64%)</td>
<td>4 (8%)</td>
<td>0</td>
</tr>
<tr>
<td>Evidence</td>
<td>3 (6%)</td>
<td>11 (22%)</td>
<td>34 (68%)</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>1 (2%)</td>
<td>14 (28%)</td>
<td>31 (62%)</td>
<td>4 (8%)</td>
</tr>
<tr>
<td>Student’s Position</td>
<td>0</td>
<td>18 (36%)</td>
<td>19 (38%)</td>
<td>3 (6%)</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0</td>
<td>13 (26%)</td>
<td>35 (70%)</td>
<td>2 (4%)</td>
</tr>
</tbody>
</table>

**Table 3. Critical thinking results for A&P II students (N=50)**

**Critical Thinking Rubric Category** | **$P$ Value**
--- | ---
Explanation of Issues | 0.00011
Evidence | 0.00004
Influence of Context and Assumptions | 0.02477
Student’s Position | 0.01588
Conclusion and Related Outcomes | 0.00014

**Table 4. $P$ values of the probable relationship between Human Biology and A&P II students for each category of critical thinking rubric results.**
Tables 5 & 6 reveal the distribution of critical thinking results for each category for white students and racial minority students in Human Biology and A&P II. We did not have race data on one student. There was no difference (\(p > 0.05\)) in the distribution of any of the critical thinking categories between races taking Human Biology and A&P II. Table 7 reveals \(p\) values of the probable relationship between white and minority Human Biology and A&P II students for each category of critical thinking rubric results.

<table>
<thead>
<tr>
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<td>2</td>
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<tr>
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<td>Count (%)</td>
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<tr>
<td>Explanation of Issues</td>
<td>10 (17%)</td>
<td>36 (61%)</td>
<td>12 (20%)</td>
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<td>Evidence</td>
<td>2 (3%)</td>
<td>8 (14%)</td>
<td>34 (57%)</td>
<td>14 (24%)</td>
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<tr>
<td>Influence of Context and Assumptions</td>
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<td>15 (25%)</td>
<td>33 (56%)</td>
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<tr>
<td>Student's Position</td>
<td>0</td>
<td>15 (25%)</td>
<td>24 (41%)</td>
<td>8 (14%)</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0</td>
<td>10 (17%)</td>
<td>41 (69%)</td>
<td>7 (12%)</td>
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</table>

*Table 5. Critical thinking results for white Human Biology and A&P II students (N=59)*

<table>
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<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
</tr>
<tr>
<td>Explanation of Issues</td>
<td>3 (7%)</td>
<td>23 (58%)</td>
<td>11 (28%)</td>
<td>2 (5%)</td>
</tr>
<tr>
<td>Evidence</td>
<td>1 (2%)</td>
<td>8 (20%)</td>
<td>22 (55%)</td>
<td>7 (18%)</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>1 (2%)</td>
<td>6 (15%)</td>
<td>25 (63%)</td>
<td>6 (15%)</td>
</tr>
<tr>
<td>Student's Position</td>
<td>0</td>
<td>10 (25%)</td>
<td>16 (40%)</td>
<td>6 (15%)</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0</td>
<td>5 (13%)</td>
<td>24 (60%)</td>
<td>8 (20%)</td>
</tr>
</tbody>
</table>

*Table 6. Critical thinking results for Human Biology and A&P II racial minority students (N=40)*

<table>
<thead>
<tr>
<th>Critical Thinking Rubric Category</th>
<th>(P) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation of Issues</td>
<td>0.26</td>
</tr>
<tr>
<td>Evidence</td>
<td>0.56</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>0.19</td>
</tr>
<tr>
<td>Student's Position</td>
<td>0.99</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0.29</td>
</tr>
</tbody>
</table>

*Table 7. \(P\) values of the probable relationship between white and minority Human Biology and A&P II students for each category of the critical thinking rubric results.*
There also was no difference ($p > 0.05$) in the distribution of any of the critical thinking categories between students of different races within the individual courses (table not shown). There was a higher percent (53%) of minority students taking Human Biology and a higher percent (72%) of white students taking A&P II. The mean GPA for racial minority students in A&P II was 3.1 while that of racial minority students in Human Biology was 2.7. The mean GPA of white A&P II students was 3.4 while that of white Human Biology students was 3.1.

Tables 8 & 9 reveal the distribution of critical thinking results for each category for male and female students in Human Biology and A&P II. There was no difference ($p > 0.05$) in the distribution of any of the critical thinking categories between male and female students in the Human Biology and A&P II. Table 10 reveals $p$ values of the probable relationship between male and female Human Biology and A&P II students for each category of critical thinking rubric results.

<table>
<thead>
<tr>
<th>Category</th>
<th>Capstone</th>
<th>Milestones</th>
<th>Benchmark</th>
<th>No Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
</tr>
<tr>
<td>Explanation of Issues</td>
<td>3 (11%)</td>
<td>15 (58%)</td>
<td>7 (27%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Evidence</td>
<td>1 (4%)</td>
<td>3 (11%)</td>
<td>13 (50%)</td>
<td>8 (31%)</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>0</td>
<td>6 (23%)</td>
<td>14 (54%)</td>
<td>5 (19%)</td>
</tr>
<tr>
<td>Student’s Position</td>
<td>0</td>
<td>5 (19%)</td>
<td>7 (27%)</td>
<td>5 (19%)</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0</td>
<td>6 (23%)</td>
<td>12 (46%)</td>
<td>7 (27%)</td>
</tr>
</tbody>
</table>

Table 8. Critical thinking results for male Human Biology and A&P II students (N=26)

<table>
<thead>
<tr>
<th>Category</th>
<th>Capstone</th>
<th>Milestones</th>
<th>Benchmark</th>
<th>No Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
<td>Count (%)</td>
</tr>
<tr>
<td>Explanation of Issues</td>
<td>10 (13%)</td>
<td>45 (61%)</td>
<td>16 (22%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>Evidence</td>
<td>2 (3%)</td>
<td>13 (17%)</td>
<td>43 (58%)</td>
<td>14 (19%)</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>1</td>
<td>15 (21%)</td>
<td>44 (60%)</td>
<td>13 (17%)</td>
</tr>
<tr>
<td>Student’s Position</td>
<td>0</td>
<td>20 (27%)</td>
<td>33 (45%)</td>
<td>10 (13%)</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0</td>
<td>9 (12%)</td>
<td>54 (73%)</td>
<td>8 (11%)</td>
</tr>
</tbody>
</table>

Table 9. Critical thinking results for female Human Biology and A&P II students (N=74)

<table>
<thead>
<tr>
<th>Critical Thinking Rubric Category</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanation of Issues</td>
<td>0.63</td>
</tr>
<tr>
<td>Evidence</td>
<td>0.37</td>
</tr>
<tr>
<td>Influence of Context and Assumptions</td>
<td>0.89</td>
</tr>
<tr>
<td>Student’s Position</td>
<td>0.10</td>
</tr>
<tr>
<td>Conclusion and Related Outcomes</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 10. $P$ values of the probable relationship between male and female Human Biology and A&P II students for each category of critical thinking rubric results.
There also was no difference ($p \geq 0.05$) in the distribution of any of the critical thinking categories between male and female students within the individual courses (data not shown). There was a higher percent of female students in Human Biology and A&P II, 70% and 78% respectively. The mean GPAs for male students in A&P II and Human Biology were 3.2 and 3.0, respectively. The corresponding mean GPAs for female students were 3.3 (A&P II) and 2.8 (Human Biology).

**Discussion**

The distribution of critical thinking results for A&P II students were significantly higher than those for Human Biology students. A&P II students performed better even though their assignment was more complex, more demanding, and longer (7 to 10 pages versus 3 to 5 pages). This is not a surprise and follows our teaching strategy. A&P II students have more degree credits than Human Biology students. A&P II is a higher-level gateway course for Health Science programs such as Nursing. These students, particularly those in competitive admission programs, are focused and committed to success in this field. They have a good GPA by MCC standards and more science experience and understanding. Human Biology is an entry-level course, and students may be taking the course to gain exposure to this science to see if they have the capability, aptitude and interest in moving forward. However, the assignments for Human Biology students were an appropriate initiation to scientific literacy and the transition in critical thinking results from Human Biology to A&P II revealed a good progression.

We believe that fitting a written assignment, as part of an WR HIP, into the science curriculum is effective and supports earlier research (Brownell et al. 2013). Adding TILT to the assignment enhances the effectiveness. Incorporating WR HIP and TILT into assignments is difficult considering time constraints. The length and difficulty of the assignment should match the level and objectives of the course.

There was no statistically significant difference in critical thinking results among racial groups or between genders. This equity in results among racial minority and white students supports previous studies (Finley and McNair 2013; Winkelmas 2013). A study assessing critical thinking on an assignment by one group of students with a mix of race in a class using WR and TILT with a similar mix of students in another class not using WR or TILT would be very helpful. The critical thinking results and GPAs support a transition in learning and scholarship from Human Biology to A&P II regardless of race or gender.

We do not have critical thinking data on individual students from Human Biology to A&P II. A future study following the progress of individual students from Human Biology to A&P II would be informative. A College’s Office of Institutional Research could help track students as they move from one class to the next.

We believe that including TILT in a HIP assignment is a technique that could help level the learning playing field (Finley and McNair 2013; Winkelmas 2013). The results of this study, as noted above do, support this premise. As a primer to the assignment, instructors should review the categories of the critical thinking rubric with students and provide a copy to the student. They should cover each category and the definition of each level and provide written examples. Students also need to understand the proper scientific language to use in order to express themselves. This could help them move up to a higher level in each rubric category (Jurecki & Wander 2012; Savage 2014). Some students found the student position perspective, thesis/hypothesis category of the critical thinking rubric challenging, and results reflect this. Spending more time reviewing the definition of this category with students might be helpful.

We also believe assignment topics like the ones used in this study should incorporate information taught in class in order to reinforce that material being taught is applicable to student degree and career aspirations. This could hold their interest and motivation (Eyler 2009).

As part of the grant agreement, the VALUE Institute assessed our student assignments for critical thinking (AAC&U 2009). Faculty at the VALUE Institute are trained and certified in the assessment process. Their involvement standardized the process and helped legitimize our results. MCC believes in this process and a number of faculty have become certified in the assessment of different essential outcomes through the VALUE Rubric Institute. Training in their certificate program has assured MCC faculty of the proper interpretation of rubrics and instilled confidence in their understanding of the process. This will enable MCC to sustain and expand the assessment process.

**Conclusion**

We believe the overall distribution of critical thinking rubric results for Human Biology and A&P II students suggest that the WR HIP along with TILT, were effective in improving students’ critical thinking in Human Biology and A&P II. MCC’s plan is to use our study design as a template to expand the process for courses using different HIPs and essential outcomes throughout MCC. Colleges interested in adopting this process should understand that one key to success of this study and expansion of this process at MCC is collaboration at all organizational levels at the college. Future studies could further assess the efficacy of this process by comparing sections of a course that incorporate the WR HIP, TILT, and VALUE rubric with those that do not, study its effectiveness among courses in different disciplines, and study the progress of individual students taking different levels of courses within their program.
About the Authors

This study was a collaborative effort. All co-authors contributed to the study. Julie A. Babulski, MS, Assistant Professor Biology has a specialty in Human Biology lecture and laboratory. Michele Finn, MS, a professor of Biology has a specialty in Human Physiology and Human Biology. Jennifer A. Hill, PhD, Professor of Biology has a specialty in Human Biology, General Biology and Human Anatomy. Jennifer A. Markham, PhD, Associate Professor of Biology has a specialty in Human Biology, General Biology and is on the WR HIP Committee. James A. Murphy, MS, Professor and chair of the Biology Department has a specialty in Human Biology and Biotechnology. MaryJo Vest, MS, Professor of Biology has a specialty in Human Biology, Anatomy and Physiology, Curriculum, and is a member of the WR HIP Committee. She also helped write and publish the case study. Artif Wahba, MD, Assistant Professor Biology has a special interest in Human Biology and human cadaver dissection. James R. Cronmiller, MA, Associate Professor Emeritus, has a specialty in Human Anatomy and Physiology, is co-chair of the MCC Undergraduate Research committee, and Chair of the HIP committee. He helped organized the study, write the design and protocol for Human Biology & A&P II assignments, and helped design, write and publish the case study. Christopher D. Wendtland, MS, Professor of Biology has a specialty in Biochemistry and helped design and write protocol of A&P II assignment. Finley A. McNair T. 2013. Assessing underserved students' engagement in high-impact practices. With an assessing equity in high-impact practices toolkit. Washington (DC): Association of American Colleges and Universities.

Literature Cited


Learning Anatomy & Physiology Virtually: Student Performance During COVID-19

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Abstract
Delivering Anatomy & Physiology (A&P) labs online became necessary in the spring of 2020 due to the COVID-19 pandemic. For four semesters (Summer 2020 through Summer 2021), our A&P1 and A&P2 labs were instructed in a virtual format. Each lab session included a one-hour synchronous session led by teaching assistants followed by at-home lab activities performed independently by students. Formative lab practice assignments were provided, and summative lab assessments were conducted weekly. Student performance in these online A&P1 labs was similar to performance during in-person labs, although more students failed or withdrew from the combined A&P1 lecture and lab course in the online environment compared to in-person. A&P2 performance data were very similar online versus in-person for both the A&P2 lab and the combined A&P2 lecture and lab course. Overall, our experience supports the conclusion that course modality is not the central factor in determining student success. http://doi.org/10.21692/haps.2022.008

Key words: anatomy and physiology, attrition rate, online, student success

Introduction
In March 2020, the global COVID-19 pandemic necessitated a shift to virtual courses. At Georgia State University, a two-week spring break in 2020 was followed by a pivot to virtual platforms for the remainder of the Spring 2020 semester. The need for a sudden and immediate shift to online courses was a topic of frequent conversation in HAPS discussion groups and town halls, as instructors and institutions came up with different plans to structure and implement new online courses. Access to these town halls and conversations with other HAPS members who had prior experience teaching A&P online was invaluable in helping us start planning our own online A&P labs. We have previously described our process in designing the framework for online Anatomy & Physiology (A&P) labs implemented in Summer 2020 (Ediger and Rockwell 2020). In total, these lab courses were offered each semester from Summer 2020 through Summer 2021, as we returned to in-person, on-campus instruction in Fall 2021. This article describes student performance in online A&P labs over these four semesters.

The A&P1 and A&P2 courses described here form a two-semester sequence, delivered as a combination lectures and laboratory sessions. The lecture component was virtual, with asynchronous lecture recordings provided in Summer 2020 and Fall 2020. In Spring 2021, lecture sessions were also virtual, but synchronous, and this continued in Summer 2021. Typically, there were four to eight lab sections that met together as one lecture, with the exception of the Fall 2020 semester in which all A&P1 or A&P2 students were combined together into a single A&P1 or A&P2 section for the asynchronous online lectures. The lecture portion of the course comprised 70% of the final course grade, while the lab portion provided the remaining 30%. Each semester, extra-credit opportunities in either lecture, lab, or both and worth a maximum of 1% were provided during the course. A&P1 and A&P2 courses were graded on an ABCDF scale, with C being the lowest passing grade, and a 70% course average the minimum for earning a C.

These A&P courses are cataloged at the 2000-level and are pre-requisites for application to an undergraduate nursing program. Historically, approximately 40% of our A&P students have been classified as “pre-nursing” students. These A&P courses also attract students from majors such as biology and chemistry as well as students who have previously completed an undergraduate degree but are interested in pursuing a health care career. A&P courses have a reputation for being content-rich, strenuous courses with large numbers of students who earn a grade of D or F or withdraw. This percentage is also known as the “DFW rate,” or the course attrition rate, as it represents students who cannot move on in their course sequence. In 2016, Russell and colleagues conducted a literature review of reports that included A&P1 DFW rates and reported a wide range of DFW rates, from 29 to 62%. They also provided data from several years of A&P1 at Jamestown Community College, showing a DFW rate of 41.6% (Russell et al. 2016).

Awareness of potentially high DFW rates, coupled with the fear of losing contact with our students in an online environment, shaped our course design decisions. Our first goal in considering how to design our online A&P lab courses...
was to maintain content coverage to prepare students for future careers in health care. A second objective was to create opportunities for student engagement, to the best of our ability, given the circumstances. During this time, students did not have the option on our campus to choose between in-person versus online coursework. The only option for students was to take online courses, and many students would be new to this process. Encouraging student engagement, then, was an essential element of our approach to mitigate the various circumstances of the online student experience during the pandemic period.

The structure that we chose for our online A&P labs included a synchronous, one-hour virtual session led by a graduate teaching assistant (TA), coupled with at-home lab activities that students completed independently. Lab activities were designed specifically for each week's topic, referencing our custom (in-house) lab manual, and making use of online anatomy and histology atlases, virtual physiology explorations, as well as a lab supply kit that students purchased from a third-party supplier. For each lab, there was a written portion for students to submit online to be graded for accuracy by the TA. After grading, assignments were available for students to review online.

Formative assessments were provided in the form of online lab practice assignments delivered through the textbook website. Lab practice assignments contained questions similar to questions on the summative assessments. Multiple attempts were available; each attempt contained half as many questions as a summative assessment. Summative assessments took the form of weekly lab assessments that students completed independently. Lab activities were recorded video proctoring.

This framework provided the basis for our lab structure during all four semesters of our online A&P labs. Labs met weekly online during the fall and spring semesters, and twice weekly during summer semesters. Required attendance at weekly virtual lab sessions was the cornerstone of our online lab experience, providing students an opportunity for instruction, guidance on the lab activity, an opportunity to ask questions, and to see other students and the TA. As a supplemental form of instruction, lab videos produced for the course were also provided through our learning management system (LMS). Each lab section had a maximum enrollment of 24 students, and was led by one TA, typically a master's student in biology, medical science, occupational therapy, physical therapy, or health policy programs. TAs received weekly training at preparatory meetings in advance of the weekly lab session.

In the A&P1 in-person lab course, there were 3 lab exams, one for each unit. The in-person A&P2 lab course had 2 lab exams, covering the first or second half of the course. Online A&P1 and A&P2 lab courses switched to a weekly assessment strategy, where students completed shorter, more frequent assessments. Regardless of the testing framework, the grading category for lab exams or weekly lab assessments counted for half of the lab grade, or 15% of the final course grade.

The summer semester consisted of a 7-week term; there were seven lab assessments in Summer 2020. In Summer 2021, the lab had only six weekly lab assessments due to the timing of the July 4th holiday. In fall or spring semesters, the course had 13 or 14 weekly lab assessments. Students were allowed two attempts for each weekly lab assessment online. During the fall or spring semesters, the lowest score for a weekly lab assessment was dropped at the end of the semester.

Summer 2020 and Fall 2020 had the same structure, which is described in our previous article (Ediger and Rockwell 2020). After Fall 2020, we made some adjustments to the lab structure for Spring and Summer 2021. For example, after Fall 2020, we changed the timing of introducing new topics and assessing students. In Fall 2020, the TA-led lab session consisted of a “review/preview” format. The first 30 minutes was dedicated to reviewing the content of the lab activity that students had just submitted for grading and preparing for the upcoming lab assessment. The second half of the session previewed the next lab activity that students would complete after the lab session. Our intention in originally choosing this timing was to allow students to ask questions about what they had just completed before being quizzed over that topic.

However, it proved to be too confusing to keep track of review topics versus new topics, and TAs observed that the review didn’t function as such, because students hadn’t studied enough for it to be a review. For Spring 2021, we simplified the timing, and kept each lab session focused on only one lab topic. Students joined the lab session for instruction about that one topic, as well as tips for completing the lab activity. The lab activity was submitted within 48 hours after the lab session, as before, and then that weekend’s lab assessment covered that same lab topic. This structure had the downside of testing students over the lab activity topic before they had received feedback on the lab activity itself. To mitigate this, students were encouraged to reach out to their TAs if they had any questions while completing the lab activities, and TAs were also encouraged to communicate with students via email if they noticed generalized misconceptions while grading lab activities.

The second change in our lab structure between Fall 2020 and Spring 2021 related to the nature of the prelab homework that was assigned. In the custom lab manual that students are required to purchase for the course, we included “PreLab” pages for each lab module. For Fall and Summer 2020, the prelab homework consisted of completing these prelab pages and submitting them prior to the lab session for grading by the TA. This meant that TAs were devoting a lot of time to grading, as they graded both prelab homework and lab activities submitted after lab. In addition to the lab manual, we had also created a library of lab videos for the course.

continued on next page
In Spring 2021, we assigned prelab homework of watching the lab videos and answering associated multiple-choice questions through our LMS. Because labs occur at various times throughout the week, the lab video homework was open on the LMS during the entire week, and some students chose to complete the prelab homework after their lab session. In retrospect, we could have avoided this by setting a due date at the beginning of each week.

We also attempted to encourage preparation for and participation in the lab sessions by implementing in-class quizzing starting in Spring 2021. These questions were either “warm-up” style questions based on the prelab homework completed outside of lab (Spring 2021) or embedded “are you paying attention to what we just covered” participation questions (Summer 2021). To include this category in our grading framework, we converted the online lab practice assignments to an extra-credit opportunity, as one part of the 1% extra-credit possible that semester. Graded categories that determined the Lab Grade (which constituted 30% of the course grade) for each semester of our online lab are shown in Table 1. Comparison with our in-person lab can be found in our previous article (Ediger and Rockwell 2020).

**Methods**

**Student Performance in A&P Courses**

Student performance data for each course were exported from the university repository of these data. Data exported included the total numbers of students who ended the course with grades of A, B, C, D, F, or W (for withdrawn). There is also a category of “O” for Other. The percentage of students achieving each letter grade was calculated using Excel. The category of “O”, which was valued between 0 and 7 students each semester, was omitted from this analysis.

**Student Performance in A&P Labs**

Numeric grade data were exported from the LMS course gradebook for each individual A&P1 or A&P2 lecture (and associated labs) course for all semesters. For A&P1 this analysis was conducted from Fall 2018 through Fall 2021; for A&P2, the analysis began at Spring 2019. After exporting the course gradebook to Excel, individual student records for each semester were combined, and the course grade, lab grade, and lab exam (or weekly lab assessment) averages were calculated for the entire group of students. In each semester, there were one to three different lecture instructors; these students were merged into one group for A&P1 or for A&P2 each semester. Lab sections have a maximum enrollment of 24 students per section. Comparisons described in the Results are descriptive in nature; student numbers and course to course variabilities do not support meaningful statistical evaluation.

The total number of students in the LMS course roster were compared with the total number of students reported in the university’s course performance data platform. The correlation was imperfect; for some semesters, the numbers matched exactly, but for other semesters the LMS contained between one and eight additional student records. For Fall and Spring semesters, the larger student enrollment yielded a discrepancy of 3% or less; in the Summer (smaller total student body), a small discrepancy had a larger effect, with the largest effect of an additional five student records in the A&P2 course of Summer 2019 causing a discrepancy of 8%. Small discrepancies between the number of students expected and the number of student records that remain in the gradebook suggest that the removal process is imprecise.

<table>
<thead>
<tr>
<th>Summer 2020</th>
<th>Fall 2020</th>
<th>Spring 2021</th>
<th>Summer 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% - weekly lab assessments</td>
<td>15% - weekly lab assessments</td>
<td>15% - weekly lab assessments</td>
<td>15% - weekly lab assessments</td>
</tr>
<tr>
<td>10% - lab activities</td>
<td>10% - lab activities</td>
<td>10% - lab activities</td>
<td>10% - lab activities</td>
</tr>
<tr>
<td>2.5% - prelab homework pages from lab manual</td>
<td>2.5% - prelab homework pages from lab manual</td>
<td>2.5% - lab video homework questions</td>
<td>2.5% - lab video homework questions</td>
</tr>
<tr>
<td>2.5% - online lab practice assignments</td>
<td>2.5% - online lab practice assignments</td>
<td>2.5% - in-class quiz</td>
<td>2.5% - in-class quiz</td>
</tr>
</tbody>
</table>

**Table 1. Grading schema for online A&P labs**

Fall 2018 represented the first semester that the A&P1 lab was based on our in-house custom lab manual; Spring 2019 was the first semester this custom lab manual was used in A&P2. For this reason, Tables 2 and 4 begin at Fall 2018, but Tables 3 and 5 start with Spring 2019.
Results

Student Performance in A&P Courses: DFW Rates and Grade Distributions

Student letter grades in A&P1 and A&P2 courses, from A to F, W for withdrawal, and the combined DFW rate are presented in Tables 2 and 3 for A&P1 and A&P2 courses, respectively. Student letter grades are also presented graphically in Figures 1 and 2. The course modality for each semester, either in-person, online, or pivot to online, is indicated next to the date of the semester.

<table>
<thead>
<tr>
<th>Semester (Modality)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>W</th>
<th>DFW</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2018 (I)</td>
<td>22%</td>
<td>29%</td>
<td>23%</td>
<td>6%</td>
<td>10%</td>
<td>10%</td>
<td>26%</td>
<td>586</td>
</tr>
<tr>
<td>Spring 2019 (I)</td>
<td>20%</td>
<td>32%</td>
<td>19%</td>
<td>9%</td>
<td>10%</td>
<td>10%</td>
<td>29%</td>
<td>404</td>
</tr>
<tr>
<td>Summer 2019 (I)</td>
<td>27%</td>
<td>32%</td>
<td>16%</td>
<td>7%</td>
<td>9%</td>
<td>8%</td>
<td>25%</td>
<td>121</td>
</tr>
<tr>
<td>Fall 2019 (I)</td>
<td>14%</td>
<td>26%</td>
<td>32%</td>
<td>11%</td>
<td>11%</td>
<td>6%</td>
<td>28%</td>
<td>527</td>
</tr>
<tr>
<td>Spring 2020 (P)</td>
<td>15%</td>
<td>28%</td>
<td>28%</td>
<td>7%</td>
<td>8%</td>
<td>15%</td>
<td>29%</td>
<td>371</td>
</tr>
<tr>
<td>Summer 2020 (O)</td>
<td>21%</td>
<td>23%</td>
<td>20%</td>
<td>6%</td>
<td>11%</td>
<td>19%</td>
<td>36%</td>
<td>159</td>
</tr>
<tr>
<td>Fall 2020 (O)</td>
<td>16%</td>
<td>22%</td>
<td>19%</td>
<td>6%</td>
<td>10%</td>
<td>27%</td>
<td>43%</td>
<td>580</td>
</tr>
<tr>
<td>Spring 2021 (O)</td>
<td>14%</td>
<td>18%</td>
<td>22%</td>
<td>14%</td>
<td>19%</td>
<td>13%</td>
<td>46%</td>
<td>412</td>
</tr>
<tr>
<td>Summer 2021 (O)</td>
<td>17%</td>
<td>21%</td>
<td>20%</td>
<td>13%</td>
<td>11%</td>
<td>17%</td>
<td>41%</td>
<td>126</td>
</tr>
<tr>
<td>Fall 2021 (I)</td>
<td>12%</td>
<td>25%</td>
<td>25%</td>
<td>13%</td>
<td>17%</td>
<td>9%</td>
<td>38%</td>
<td>513</td>
</tr>
</tbody>
</table>

The Instruction Modality each semester was either I (In-person), O (Online), or P (Pivot to online).

Table 2. Student performance in A&P1 course

Figure 1. Student performance in A&P1 courses. Student course grades for each semester from Fall 2018 through Fall 2021 are shown.
Learning Anatomy & Physiology Virtually: Student Performance During COVID-19

For A&P1, in-person DFW rates prior to the pandemic ranged from 25-29%. In our online course, DFW rates ranged from 36-46%, with the highest DFW rate of 46% occurring in Spring 2021. The percentage of students withdrawing from the course ranged from 6-10% before Spring 2020; this percentage was 13-27% for our online A&P1 courses, Summer 2020 through Summer 2021. The DFW rate was 43% in Fall 2020 and 46% in Spring 2021. Between Fall 2020 and Spring 2021, the W% dropped from 27% to 13%, but the F% increased from 10% to 19%.

For A&P2, in-person DFW rates before Spring 2020 ranged from 26-33%. In the online A&P2 course, DFW rates ranged from 23-30%. The percentage of students withdrawing from the course ranged from 4-8% before Spring 2020; this percentage was 7-16% in online A&P2 courses.

Student Performance in A&P Labs: Lab Grade Distributions
Student grade averages generated from LMS gradebook data are shown in Tables 4 and 5, for A&P1 and A&P2 respectively. Grades are shown as % grade averages for the entire course, for the 30% portion of the lab only, and for the lab exam or lab assessment gradebook category. These data represent students who earned an A, B, C, D, or F in the course. Students who received a grade of W for the course are not included, because they are routinely removed from the LMS roster when registration data updates.

The Instruction Modality each semester was either I (In-person), O (Online), or P (Pivot to online).

Table 3. Student performance in A&P2 Course

<table>
<thead>
<tr>
<th>Semester (Modality)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>W</th>
<th>DFW</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2019 (I)</td>
<td>22%</td>
<td>23%</td>
<td>27%</td>
<td>14%</td>
<td>9%</td>
<td>4%</td>
<td>27%</td>
<td>369</td>
</tr>
<tr>
<td>Summer 2019 (I)</td>
<td>23%</td>
<td>34%</td>
<td>16%</td>
<td>10%</td>
<td>8%</td>
<td>8%</td>
<td>26%</td>
<td>61</td>
</tr>
<tr>
<td>Fall 2019 (I)</td>
<td>19%</td>
<td>23%</td>
<td>25%</td>
<td>15%</td>
<td>10%</td>
<td>8%</td>
<td>33%</td>
<td>244</td>
</tr>
<tr>
<td>Spring 2020 (P)</td>
<td>19%</td>
<td>34%</td>
<td>26%</td>
<td>6%</td>
<td>4%</td>
<td>12%</td>
<td>22%</td>
<td>344</td>
</tr>
<tr>
<td>Summer 2020 (O)</td>
<td>22%</td>
<td>26%</td>
<td>26%</td>
<td>12%</td>
<td>11%</td>
<td>4%</td>
<td>26%</td>
<td>85</td>
</tr>
<tr>
<td>Fall 2020 (O)</td>
<td>11%</td>
<td>29%</td>
<td>30%</td>
<td>5%</td>
<td>8%</td>
<td>16%</td>
<td>30%</td>
<td>273</td>
</tr>
<tr>
<td>Spring 2021 (O)</td>
<td>18%</td>
<td>33%</td>
<td>25%</td>
<td>6%</td>
<td>7%</td>
<td>10%</td>
<td>24%</td>
<td>325</td>
</tr>
<tr>
<td>Summer 2021 (O)</td>
<td>25%</td>
<td>33%</td>
<td>20%</td>
<td>7%</td>
<td>10%</td>
<td>7%</td>
<td>23%</td>
<td>61</td>
</tr>
<tr>
<td>Fall 2021 (I)</td>
<td>20%</td>
<td>25%</td>
<td>27%</td>
<td>10%</td>
<td>11%</td>
<td>7%</td>
<td>28%</td>
<td>227</td>
</tr>
</tbody>
</table>
Learning Anatomy & Physiology Virtually: Student Performance During COVID-19

In the A&P1 lab, before Spring 2020, lab grade averages were consistently 72 or 73%. This continued in the online environment, with lab grade averages of 70-73% from Summer 2020 through Summer 2021. In A&P2, lab grades before Spring 2020 were very similar to A&P1 lab grades, with a range of 70-73%. In the online environment, lab grades matched these scores or increased, with a highest average of 79% in Spring 2021.

Student Performance in A&P Labs: Comparison of Lab Exams versus Weekly Lab Assessments

In Tables 4 and 5, the Lab Exam column represents either the averages of lab exams or weekly lab assessments. For the A&P1 lab in-person, lab exam averages ranged from 62-69%. In the online lab course, weekly lab assessment averages ranged from 62-67%. For A&P2, in-person lab exam scores averaged between 63-67%; online, A&P2 weekly lab assessment scores averaged from 62-75%.

As we returned to an on-campus lab experience in Fall 2021, we chose to continue the weekly lab assessment testing system. In the on-campus lab, students have only one attempt to complete the weekly lab assessment during the lab itself, with TA proctoring. For Fall 2021, we chose to drop the lowest two weekly lab assessments, partly as a concession to the continued stress of the COVID-19 pandemic and the challenges faced by faculty, staff, and students returning to campus. The weekly lab assessment average for the A&P1 lab in Fall 2021 was only 60%; the A&P2 lab had a weekly lab assessment average of 69%, similar to the lab exam and lab assessment averages of previous semesters.

Discussion

The DFW rates in our A&P1 course suggest that students were not as successful in the online environment as they typically are in an in-person course when there is no pandemic. Our DFW rates of 43 and 45% for Fall 2020 and Spring 2021 were higher than the DFW rate of 25-29% seen before Spring 2020. It appears that the higher DFW rate for the A&P1 course in Fall 2020 was largely due to the increase in students withdrawing from the course, with a 27% W rate that semester. In Fall 2020, we had an extended deadline for students to withdraw from courses, which may have affected the W rate that semester. However, Fall 2020 was also the first semester that taking an online course was required for any student intent on taking college classes at our campus. Students did not have another option, and this may have been the first online course experience for many students. A&P1 in Summer 2020 was also online, as we began to offer only online courses that summer, but our summer enrollment is much smaller than fall or spring, and summer courses occur at twice the pace, yielding a different, more intense experience.

<table>
<thead>
<tr>
<th>Semester (Modality)</th>
<th>Grade Averages</th>
<th>No. of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entire Course</td>
<td>Lab Portion</td>
</tr>
<tr>
<td>Fall 2018 (I)</td>
<td>77%</td>
<td>73%</td>
</tr>
<tr>
<td>Spring 2019 (I)</td>
<td>77%</td>
<td>72%</td>
</tr>
<tr>
<td>Summer 2019 (I)</td>
<td>75%</td>
<td>73%</td>
</tr>
<tr>
<td>Fall 2019 (I)</td>
<td>73%</td>
<td>72%</td>
</tr>
<tr>
<td>Spring 2020 (P)</td>
<td>76%</td>
<td>71%</td>
</tr>
<tr>
<td>Summer 2020 (O)</td>
<td>74%</td>
<td>70%</td>
</tr>
<tr>
<td>Fall 2020 (O)</td>
<td>75%</td>
<td>72%</td>
</tr>
<tr>
<td>Spring 2021 (O)</td>
<td>68%</td>
<td>71%</td>
</tr>
<tr>
<td>Summer 2021 (O)</td>
<td>73%</td>
<td>73%</td>
</tr>
<tr>
<td>Fall 2021 (I)</td>
<td>71%</td>
<td>66%</td>
</tr>
</tbody>
</table>

*Lab Exams were either lab practical exams, or weekly Lab Assessments (from Summer 2020 onwards).
Although we attempted to stress to students enrolling in online A&P courses in Fall 2020 that these would be rigorous courses, students may have been under the false impression that the A&P1 course would be easier because of the online modality. Communication with students revealed that some students were surprised to find that attendance at synchronous virtual lab sessions was required. Other students reported being overcommitted and stressed for time, having registered for 18 credit hours of online coursework without appropriate estimations of the amount of time required to complete the workload for each course. In addition, with most courses structured within an asynchronous framework, students were able to register for a full course load while also working full-time and/or performing caregiving duties at home. This created stress for students who did not realistically have enough time to complete their coursework. For some, this may have been compounded by additional challenges within their home environments for a variety of practical, logistical, and/or technical reasons.

In Spring 2021, we expected the course to be more successful, as the student body was now in its second semester of online coursework. What we saw in A&P1 was a DFW rate that appeared to increase slightly, although the percentage of students withdrawing from the course declined to near normal levels. Looking at the course grade data, we saw that the course average for A&P1 in Fall 2020 was only 68%; this was the only semester for which the course average was below 70% (minimum passing grade). According to the grade distribution data shown in Table 2, the percentage of students earning a grade of F in A&P1 during the Spring 2021 semester was 19%, an important factor driving the course grade average down. Anecdotally, students reported that they wished to withdraw from the course, but they had already reached the maximum number of “W” courses for their academic careers, suggesting that students who would have withdrawn from the course were still on the roster but not attempting successful completion of the course.

The A&P2 course has the advantage of requiring successful completion of A&P1 as a pre-requisite. A&P2 course grade data and lab grade data showed student performance that was very similar in the online versus in-person course modality. Data for successful completion of A&P2 during our return to campus in Fall 2021 was similar to other semesters. Interestingly, Adams and Dewsbury (2021) recently reported a shift in student perceptions occurring between the first and second course in a two-semester A&P sequence. Perhaps we are seeing the results of a similar shift in student perception that increases student success in A&P2 compared to A&P1.

The weekly lab assessment average scores in the A&P2 lab are especially encouraging. During the pandemic, we invested in developing a question bank which was used to randomly generate questions for lab practice assignments. These assignments were available each semester; students had multiple attempts to complete these lab practice assignments, which mirror the weekly lab assessments in content and question structure. The 75% weekly lab assessment average seen in A&P2 in Spring 2021 may be an anomaly; alternatively, it may indicate that with appropriate practice, students can be more successful on these summative assessments. Investing in providing multiple opportunities for students to practice ahead of the summative assessment is useful for the course overall.

Several limitations must be kept in mind when comparing performance data from one semester to another. This data set does not represent data from a controlled environment where only one variable is manipulated. From one semester to the next, we often had different lecture instructors, with up to three individuals teaching different sections of an A&P1 or A&P2 lecture in a given semester. When we moved to virtual labs, we chose to not continue with large summative lab practical exams, partly because we hoped that regular, smaller summative lab assessments would enhance student learning. As a result, comparing in-person lab exams to online lab assessments was an imperfect comparison. Finally, additional tweaking between Fall 2020 and Spring 2021 resulted in changes to the flow of lab content and assessments, although the basic framework of a required 60-minute synchronous virtual meeting between TAs and students was unchanged.

There are a wide variety of online experiences created for science labs and there does not appear to be consensus about best practices and/or outcomes (Brinson 2017, Faulconer and Gruss 2018). In some instances, science labs were shown to be successful with virtual or hybrid approaches compared to fully face-to-face (Massey et al. 2021; Faulconer and Gruss 2018; Gronlien et al. 2021). However, there are also reports of students being less successful in virtual formats (Brown and Peterson 2021; Romeo et al. 2021).

The Brown and Peterson (2021) study is especially interesting because all students enrolled in the same asynchronous A&P1 lecture and then they chose either a face-to-face or an online A&P1 lab, each of which involved the same lab activities and all the same assessments. In this 101-student A&P1 course, the face-to-face group had a better passing rate, higher course grade average, and lower withdrawal rate compared to the group of students taking the asynchronous online lab, suggesting that completing the lab activities in the lab room itself correlated with improved student outcomes. It is tempting to wonder if there was also a student factor driving the choice of an asynchronous, virtual versus a scheduled, in-person lab in this study, perhaps related to student motivation or the ability to stay on task during an online activity.

Brown and Peterson (2021) suggested that the key difference in the student lab experience was access to models and a cadaver pro-section, which enabled students to develop three-dimensional knowledge of anatomical structures through kinesthetic learning. In 2017, Van Nuland found
that handling a physical skeleton yielded improved learning compared to accessing a virtual anatomy tool. Interestingly, Faulconer and Gruss (2018) noted that the use of remote lab kits can create a blend between traditional labs focused on providing hands-on activities and purely virtual, online labs. In our virtual lab structure, we built in as much hands-on experience as possible by asking students to purchase a lab supply kit with dissection specimens, in addition to utilizing online textbook resources and a 3D anatomy app.

The experience of teaching and learning during a pandemic has undoubtedly affected student performance, student satisfaction with learning, and student stress in general. Living in lockdown amidst the toll and risks of COVID-19 for human health has created a stressful teaching and learning environment. Goyal and colleagues (2022) reported that chemistry students at Xavier University were less engaged in the summer of 2020, had difficulty adapting to online education, and experienced various social, emotional, and economic stresses. It will surprise no one that students have reported increased day-to-day difficulties as well as mental health challenges (Goyal et al. 2022; Kecojevic et al. 2020). In one survey, students enrolled in General Chemistry ranked “distractions at home” as more difficult on a Likert scale than successfully completing the course (Villanueva et al. 2020). We must expect that there have been educational costs due to the pandemic. As one example, a survey of seven economics courses taught in the spring of 2020 found that average assessment scores declined by 0.2 standard deviations (Orlov et al. 2021). Furthermore, an analysis of the performance of general chemistry students noted higher W rates in the spring of 2020 (Villanueva et al. 2020). A complete picture of the effect of COVID-19 on education is yet to come.

In the midst of these pandemic-related challenges, many instructors have found ways to keep engaged with students. The chemistry instructors at Georgia Gwinnett College shared our concerns about losing student engagement in the pivot to online instruction in the spring of 2020, which led them to incorporate specific active learning strategies such as breakout sessions, polling, and small group projects (Villanueva et al. 2020). The survey of economics courses also reported a wide variety in educational impact, that varied according to instructor experience teaching online, and usage of active learning strategies such as small group activities and projects (Orlov et al. 2021).

A survey of 10,092 higher education students from 10 countries across 4 continents during the pandemic’s first wave identified the “teacher’s active role” as one of three major factors influencing the quality of online learning (Keržič et al. 2021), which can be affirming to those of us seeking to reach students through online education. An interesting byproduct of the recent mandatory online lab experience is an anecdotal increase in student appreciation for hands-on lab experiences, which has been discussed in HAPS town halls. This has also been noted in a recent report that students in an online cadaver-based anatomy lab had similar test scores but lower confidence and satisfaction with virtual learning, especially because they could not learn from the cadaver in person (Wilhelm et al. 2022).

In summary, our experience of online A&P labs suggests that it is possible to maintain content coverage, a minimal level of student engagement, and provide students with an opportunity to successfully complete the course and progress in their pathway to a career in health care. Although our data are promising, they should still be viewed through a “pandemic lens”, understanding that students and faculty were operating in an abnormally stressful environment and may not have been prepared for online instruction and learning. Online courses require personal initiative and accountability which makes online coursework a good fit for a specific type of student with a high level of intrinsic motivation. These data represent the experiences of a large group of students who may or may not have chosen to take online courses, if online course delivery was one option rather than the only option. Our experience also supports the findings of others who have reported that the modality of instruction, either in-person or online, is not the biggest factor in determining student performance (Attardi et al. 2018; Biel and Brame 2016).

Earning an A or B in A&P courses is an important step in progression toward a career in health care. Although the specific requirements for different health care programs vary, success in A&P makes a student a more competitive candidate for entry into a professional program and provides a strong foundation of knowledge of human body function upon which to build. Anecdotally, faculty instructors are still receiving grateful emails from students who have entered professional programs, such as nursing, physiotherapy or medical education. While it may feel as though there are fewer of these students who have been able to progress during the pandemic, our data suggest that regardless of delivery method, there were still many students who were successful in the courses and are now prepared to continue their pursuit of a career in health care.

About the Author
Tracy Ediger, MD, PhD, is employed as an Academic Professional for A&P education at Georgia State University. She teaches in the two-semester A&P course for pre-health professions students, supervises the A&P instructional labs, and trains teaching assistants.
Literature Cited


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