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Disparities in Prerequisites Between Anatomy and Physiology for Health Majors and Physiology for Biology Majors

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Abstract
Learning physiology requires students to apply physical and chemical principles to the study of biological systems. Unfortunately, many undergraduate anatomy and physiology (A&P) students are unprepared for this due to a lack of prerequisite knowledge in physics and chemistry. This lack of prerequisite knowledge of chemistry and physics makes learning physiology especially difficult and may contribute to the high failure rates among A&P courses nationwide. However, undergraduate physiology courses catering to biology majors often require more stringent chemistry and physics prerequisites that help prepare students to learn physiology. This study compared prerequisite requirements in chemistry and physics between A&P classes for health-related majors and physiology classes for biology majors across numerous four-year institutions and found striking differences in prerequisite preparation between the two groups. 62% of physiology courses for biology majors required a chemistry prerequisite while only 18% of A&P classes for health-related majors had the same requirement. As a result, students entering physiology courses for biology majors may have a better foundation upon which to learn physiology than students entering A&P for health-related majors. https://doi.org/10.21692/haps.2022.019

Key words: anatomy and physiology, prerequisite, physiology, chemistry, biology, student success

Introduction
Physiology is a branch of the biological sciences that focuses on understanding the functions of living organisms across various levels of biological organization (Martini et al. 2018). Effective learning of physiological concepts requires students to integrate knowledge of chemical and physical principles as they relate to the functions of biological systems (Hill et al. 2008; Michael et al. 2017). Thus, many would regard a functional understanding of chemistry and physics to be a foundation upon which physiological knowledge is built (Figure 1).

College-level physiology is taught to two main student audiences. First, physiology is a core component of the biology major curriculum. Depending on the program and the concentrations chosen by the student, physiology courses for biology majors can include animal physiology, human physiology, plant physiology, or even more specialized subdivisions of physiology. The second major audience for physiology is comprised of students pursuing careers in health-related fields, such as nursing or dental hygiene. While the curricula differ among programs, many health-related majors take physiology through a combined anatomy & physiology (A&P) course that focuses on human-specific topics and is commonly taught across two semesters. Many students take A&P in their first year of college, and in many instances, success in A&P can be a determining factor for entrance into competitive-admission programs like nursing.

Without question, physiology is considered a difficult subject as it requires the integration of numerous concepts spanning different scientific disciplines. A survey conducted by Michael (2007) found that many post-secondary physiology educators believe the “characteristics” of the discipline of physiology, such as a requirement for causal reasoning and knowledge integration, was a major reason
students have difficulty learning physiological concepts. Additionally, this same survey found that physiology educators believe a student’s prerequisite knowledge and skillsets are important determinants of success in learning physiology (Michael, 2007). Furthermore, Michael et al. (2017) pinpointed the need for students of physiology to apply their existing knowledge of chemistry and physics to grasp physiological concepts. They also noted that students often struggled to transfer knowledge between subjects (e.g., from chemistry to cellular physiology) or within subjects (e.g., from one physiological system to another within an organism).

A&P is often considered a “weed out” or “gatekeeper” course with high rates of attrition (i.e., failure and withdrawal) across institutional types and locations. In a study conducted from 2005 to 2010 at a two-year open access institution in the midwestern United States, Gultice et al. (2015) found an attrition rate of 32.7%. In a similar study from 1999 to 2005 at Houston Baptist University, Hopp (2009) reported an attrition rate of 43.6%. At the University of Southern Indiana, Hopper (2011) found a failure rate (grade of D or F) of about 58%. The same trend of high attrition has also been seen internationally (Higgins-Opitz et al. 2016). In a longitudinal study at the University of South Florida, McCoy and Pierce (2004) found that enforcement of course-specific entry requirements. While prerequisites vary, the most common prerequisite is the completion of another course in the curriculum sequence. For example, a student must successfully complete Biology 101 with a certain grade before enrolling in Biology 102. This ensures that students move through the curriculum in a defined manner and possess the requisite knowledge from previous classes to effectively learn new course material. Studies have looked at the effects of prerequisites on student success in undergraduate A&P and biology classes, and this has been the subject of major review by the Educational Research Task Force of the Human Anatomy & Physiology Society (Hull et al. 2016). In a longitudinal study at the University of South Florida, McCoy and Pierce (2004) found that enforcement of undergraduate prerequisites resulted in a marked drop in both failure and withdrawal rates for biology courses. Effective prerequisite courses should provide students with the foundational knowledge and skillsets needed to succeed in later courses. Michael et al. (2017) provided a list of 15 core concepts that physiology education must cover for students to effectively understand the functionality of physiological systems. One of these core concepts revolves around the student’s ability to apply laws of chemistry and physics to understanding the functions of biological organisms. Other core concepts of physiology include cell-cell communication, cell membrane transport, energy, flow down gradients (e.g., diffusion, transport), and mass balance (Michael et al. 2017). These concepts build upon topics that could first be introduced and mastered in an introductory chemistry or physics course. From these core concepts, it becomes apparent that for students to successfully understand physiological systems, they must possess a baseline knowledge of both chemistry and physics. Therefore, it can be reasoned that the study of physiology should be preempted by the study of chemistry and physics.

Research testing the effectiveness of prerequisites for a course in biology remain limited (Forgey et al. 2020; Harris et al., 2004). However, data suggest that chemistry prerequisites can be effective at increasing A&P performance. Hopp (2009) compared the mean GPA earned by A&P students who either had or had not successfully completed chemistry. Results showed that students who had completed chemistry earned a mean A&P GPA of 2.64 compared to 1.88 for A&P students who had not.

The core concepts of physiology (Michael et al. 2017) taught in A&P and physiology courses for biology majors are largely the same. Topics range from cellular physiology and energetics to systems-level physiology (e.g., function of the nervous system). Because the topics covered are largely the same, one would expect that curricula for both groups are organized similarly and that both courses require the same prerequisite knowledge for enrollment. However, in practice, the prerequisite requirements for the two classes can be wildly different. This study compares the prerequisite requirements for both A&P for health majors and physiology for biology majors across colleges and universities that offer both courses. The analysis of this study focused specifically on chemistry and physics courses as prerequisites as they are the most directly related to the understanding of physiology (Michael et al. 2017). Differences found between the two curricula suggest potential contributing factors to the high attrition rates seen in A&P that may be mitigated by taking a standard approach to physiology curricula.
Methods

Institutional and Course Selection Criteria
Fifty 4-year colleges and universities in the Midwestern United States were surveyed. Only institutions that offered both physiology for health-related majors and physiology for biology majors were included in the analysis. The most common method of offering physiology for health majors was via a combined Anatomy & Physiology course. However, some colleges and universities separate these into distinct courses, and thus courses listed as covering physiology for health majors were included in this analysis.

Data Collection
Data for this study was collected from public-facing course catalogs and course descriptions found on college and university websites. A detailed course search was performed in each institution’s online registrar system to determine the course offerings and prerequisite requirements for course registration (Figure 2). Course title, course number, and any listed prerequisites for registration were documented. Special consideration was given to recording whether the institution listed either chemistry or physics courses as prerequisites for physiology course registration. When a non-chemistry or non-physics course was listed as a course prerequisite, the catalogue was searched to determine the prerequisite for that non-chemistry or non-physics course.

Results
Figure 3 shows the percentage of institutions that implemented chemistry and physics prerequisite requirements for physiology courses for health majors and physiology courses for biology majors. Chemistry was the more common prerequisite in both instances compared to physics. Of the institutions surveyed, only 18% required students enrolling in physiology for health majors to complete a chemistry prerequisite course. The vast majority of institutions (82%) had no requirement for students to complete formal chemistry prerequisites prior to enrolling in physiology for health majors. Alternatively, these same institutions were far stricter about requiring chemistry prerequisites for biology majors enrolling in physiology, with 62% of institutions requiring a chemistry prerequisite. Surprisingly, 0% of institutions surveyed required a physics prerequisite for A&P and only 4% required physics as a prerequisite for biology majors.

Figure 2. Methods for determining course prerequisites from course catalogues.
Disparities in Prerequisites Between Anatomy and Physiology for Health Majors and Physiology for Biology Majors

Many institutions that were surveyed required alternative prerequisites other than chemistry or physics. Table 1 shows the most common alternative requirements for enrollment into both A&P for health-related majors and physiology for biology majors. Physiology for biology majors frequently required the completion of another college-level biology course (96% of institutions), but this was much less prevalent among A&P courses (26% of institutions). Instead, high school biology was a suitable replacement for college-level biology for 14% of A&P courses, but 0% of physiology courses for biology majors.

**Discussion**

Physiology is a subdiscipline of the biological sciences that integrates chemical and physical properties into the understanding of how biological systems function. To fully grasp physiological concepts, students need foundational knowledge of chemistry and physics so they can build upon pre-existing knowledge and apply it to the understanding of physiological systems (Michael et al. 2017). The data presented here demonstrate that many institutions are preparing physiology students differently according to their majors. Physiology for biology majors appears to require more stringent prerequisites that frequently include both chemistry and lower-level biology courses that can help build foundational knowledge needed to succeed in physiology. A&P courses appear to require less stringent prerequisites, with less emphasis on requiring prior chemistry and biology courses.

The extent to which this discrepancy in prerequisite preparation impacts overall student performance in physiology is still relatively unexplored (Forgey et al. 2020). It is important to note that the scope of this study was not to collect data to test the hypothesis of whether prerequisite

<table>
<thead>
<tr>
<th>Prerequisite</th>
<th>Required for A&amp;P</th>
<th>Required for Physiology for Biology Majors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology college course (including health sciences/excluding anatomy)</td>
<td>26%</td>
<td>96%</td>
</tr>
<tr>
<td>Biology course high school</td>
<td>14%</td>
<td>0%</td>
</tr>
<tr>
<td>Math placement score</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Math college course</td>
<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>Special permission granted by instructor</td>
<td>6%</td>
<td>18%</td>
</tr>
<tr>
<td>Anatomy</td>
<td>4%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Table 1. Non-chemistry and physics prerequisites across institutions surveyed. Data show the percentage of institutions that listed the prerequisite.*

continued on next page
Disparities in Prerequisites Between Anatomy and Physiology for Health Majors and Physiology for Biology Majors

status influences outcomes in physiology courses. Instead, the goal was to explore how institutions are approaching the implementation of prerequisites for different student populations. The findings presented here open an avenue for future exploration into the impact these prerequisites have on the outcomes seen in both student populations.

One challenge to pinpointing a cause-and-effect relationship between prerequisite preparation and outcome of A&P courses is the existence of numerous confounding variables that may impact student performance and attrition rates. In their analysis of the topic, Hull et al. (2016) identified several “non-controllable” factors that may impact student attrition in A&P. These include demographic factors such as gender, socioeconomic status, and minority status. Characteristics of the institution itself, such as affordability of tuition, may also play a role in attrition rates (Hull et al. 2016). Although not specifically measured in this analysis, it is also likely that students are enrolling in these two courses at different stages of their undergraduate education. The lack of prerequisite requirements for A&P, in addition to program structure, likely results in students taking A&P early in their undergraduate studies. Alternatively, more extensive prerequisite requirements for physiology for biology majors likely delays enrollment in the course until later years of undergraduate study. This difference may influence outcome data on success, failure, and withdrawal rates when comparing the two courses.

Regardless of the cause, when students enter a physiology course lacking prerequisite knowledge, there are two major options to get students “up-to-speed.” The first option is to provide students with a list of topics that they should already know and point them toward resources that can be used to acquire the knowledge outside of class. This may include students working on their own, reading texts, participating in tutoring, or working with the instructor outside of class (e.g., during office hours). The second option is for the instructor to utilize class time to cover the necessary background information needed to understand the physiological concepts of the course. This requires A&P instructors to carve time out of their already packed course schedules to front-load their classes covering basic chemistry and physics principles.

Table 2 shows a sample lecture schedule from A&P I during the Fall 2021 semester at an institution where students are not required to complete chemistry or physics prerequisites. The sample schedule shows that the instructor is spending 2.5 of the total 15 weeks, or 16.67% of the total in-class instructional time, covering and assessing principles of chemistry. The remaining extensive learning outcomes of the course must then be covered in the remaining 12.5 weeks, leading to a crammed schedule and a need to cover topics at a faster pace. This leaves both students and instructors at a disadvantage and with less class time to devote to covering the actual physiology learning objectives set by the institution.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to A&amp;P</td>
</tr>
<tr>
<td></td>
<td>Homeostasis</td>
</tr>
<tr>
<td>2</td>
<td>Chemistry Review</td>
</tr>
<tr>
<td></td>
<td>Organic Chemistry &amp; Biochemistry</td>
</tr>
<tr>
<td>3</td>
<td>Organic Chemistry &amp; Biochemistry</td>
</tr>
<tr>
<td></td>
<td>Organic Chemistry &amp; Biochemistry</td>
</tr>
<tr>
<td>4</td>
<td>Lecture Exam 1</td>
</tr>
<tr>
<td></td>
<td>Cell Biology</td>
</tr>
<tr>
<td>5</td>
<td>Cell Biology</td>
</tr>
<tr>
<td>6</td>
<td>Cell Biology</td>
</tr>
<tr>
<td></td>
<td>Tissues &amp; Integumentary System</td>
</tr>
<tr>
<td>7</td>
<td>Skeletal System</td>
</tr>
<tr>
<td></td>
<td>Skeletal System</td>
</tr>
<tr>
<td>8</td>
<td>No Class – University Closed</td>
</tr>
<tr>
<td></td>
<td>Lecture Exam 2</td>
</tr>
<tr>
<td>9</td>
<td>Neural Tissue</td>
</tr>
<tr>
<td>10</td>
<td>Neural Tissue</td>
</tr>
<tr>
<td></td>
<td>Muscular System</td>
</tr>
<tr>
<td>11</td>
<td>Muscular System</td>
</tr>
<tr>
<td></td>
<td>Lecture Exam 3</td>
</tr>
<tr>
<td>12</td>
<td>CNS</td>
</tr>
<tr>
<td></td>
<td>No Class – Veterans Day</td>
</tr>
<tr>
<td>13</td>
<td>CNS</td>
</tr>
<tr>
<td>14</td>
<td>Sensory Pathways &amp; Neural Integration</td>
</tr>
<tr>
<td></td>
<td>No Class Thanksgiving</td>
</tr>
<tr>
<td>15</td>
<td>Sensory Pathways &amp; Neural Integration</td>
</tr>
<tr>
<td></td>
<td>Autonomic Nervous System</td>
</tr>
<tr>
<td></td>
<td>Finals Week</td>
</tr>
<tr>
<td></td>
<td>Lecture Exam 4</td>
</tr>
</tbody>
</table>

Table 2. Sample A&PI schedule. Schedule was taken from the Fall 2021 semester.
There are numerous potential approaches that institutions can take to ensure that students entering A&P have adequate chemistry and physics knowledge to succeed in A&P. First, students could be required to complete prerequisite courses in college before enrolling in A&P. While requiring students to take full courses as prerequisites may not be feasible, Abdullahi and Gannon (2012) showed that students who participated in a two-week pre-A&P workshop performed significantly better and had lower attrition rates than students who did not participate. Additionally, Hopper (2011) found that students enrolled in a supplement course to A&P had improved performance and lower attrition. If the option of additional coursework is not feasible, a requirement could be set that necessitates students to have successfully completed high school chemistry and/or physics within a meaningful timeframe (e.g., less than five years before enrolling in A&P). Yet another option would be to have students wishing to enroll in A&P complete a chemistry and/or physics placement test. Preferably, these placement tests would be designed by A&P faculty and cover the most pertinent chemistry and physics principles required for A&P success.

It remains unclear why institutions would require prerequisites for enrolling in physiology for biology majors but not for A&P. One potential reason is the timing within the program when students take their respective physiology courses. Students often take A&P in the freshman year and the course is required for entry into programs such as nursing or dental hygiene. Requiring students to complete a prerequisite before enrolling in A&P would therefore delay entry into these health-related programs, elongate the time to graduate, and potentially increase the likelihood of dropping out of the program (Abou-Sayf 2008). While this may be true, it does not consider the fact that many students who enroll in A&P must retake the course, sometimes repeatedly, in order to pass.

In their analysis, Higgins-Opitz and Tufts (2014) found that 64% of students who failed their A&P course were taking the course for the first time, and thus would need to repeat the course to be able to pass. Additionally, they found that the remaining 36% of students failing their A&P course were students repeating the course. These students would need to take the class a third time to pass (Higgins-Opitz and Tufts 2014). It could certainly be argued that many students would have the same or shorter time to graduation by enforcing stricter prerequisites. It should also be noted that increasing or strictly enforcing prerequisite requirements may have a negative impact on enrollment (Abou-Sayf 2008). As institutions suffer from enrollment declines and compete for students, they are therefore less likely to implement curriculum strategies that may reduce enrollment, even if these same strategies are effective at increasing student success.

Finding the appropriate curriculum balance between prerequisite requirements and time-to-degree completion is paramount to ensuring student success in health-related programs. While the pros and cons of prerequisite requirements for A&P have been widely debated, the data presented in this study show that the approach taken by institutions in implementing prerequisites varies widely. Future studies should link this disparity in prerequisite requirements to metrics of student success in A&P to better guide curricular development and enhance student success.

About the Author
Dr. Mark Tran is an associate professor of biology at the University of Cincinnati Blue Ash College. He teaches courses in anatomy & physiology and general biology.

Literature Cited


A Comparison of Student Preferences for Presentation Format in an Undergraduate Human Anatomy and Physiology Course Before and After the Pandemic

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Abstract
Recently, we saw a forced transition in educational practice from traditional methods to online and virtual learning as higher education, along with nearly all aspects of society, was disrupted due to the COVID-19 pandemic. As many of us have returned to face-to-face instruction, questions remain regarding modes of instruction and what forms of presentation are preferred among students. This study was done to gain the students’ perspective on the presentation of content in an undergraduate human anatomy and physiology course by surveying students both before and after the pandemic. Students were asked about their preferences regarding presentation of new material, conceptual and non-conceptual, and options to review content from the lecture or laboratory portions of the course. Our results indicate that, despite a trend toward virtual instruction and despite finding more students post-pandemic seemingly more comfortable with independent study, traditional educational methods such as face-to-face PowerPoint presentations and additional time in the laboratory are still valued by students. https://doi.org/10.21692/haps.2022.020

Key words: anatomy, physiology, education, preferences, format, pandemic

Introduction
The COVID-19 pandemic disrupted nearly all aspects of society including higher education. In response to the pandemic, there was a transition in educational practice from traditional forms of teaching such as didactic lectures and hands-on laboratory instruction to online and virtual learning. Students and instructors alike were thrust into utilizing various technologies to help ensure instructional goals were met during this time. Much of the emerging research on the effects of the pandemic has focused on mode of delivery – online, hybrid and face-to-face – and correlations with student performance (Cowan et al. 2022; Ediger 2022; Wilhelm et al. 2020).

The same issue of identifying the appropriate presentation format that not only benefits student success but is also delivered in a way students prefer, applies to combined courses such as anatomy and physiology. Although anatomy laboratories have typically been taught face-to-face, when possible, to allow visualization of anatomic structures and their relationship to each other in threedimensions utilizing models or dissection, the instructional delivery of material as it relates to physiology occurs in a variety of ways. As with other disciplines, lecture-based instruction with some form of multimedia presentation is most commonly used to deliver the content.

Prior to the pandemic, college instructors were increasingly providing students with online notes and this trend has become more prevalent since the pandemic, although research is considered equivocal on how such notes affect student outcomes and which form of notes are most beneficial (Vijay 2021). Several studies conducted prior to the pandemic examined providing students with no notes versus full notes or partial notes versus full notes in their classes (Barnett 2003; Cornelius and Owen-DeSchryver 2008; Raver and Maydosz 2010). These studies found that students who received partial notes performed better on exams, including on conceptual questions during the cumulative final examination, than students who received full notes or no notes at all.

At our institution, anatomy and physiology students are given partial notes for the lecture content before class and are provided the chance to complete notes during in-class PowerPoint presentations that are explained verbally by the instructor. Although no internal studies have been done to directly measure student success using this method, we have found that student attendance is better when we do not provide students with fully completed notes and this is consistent with the findings of Cornelius and Owen-DeSchryver (2008). One interesting aspect of the format
options that has not been explored in any depth is student preference. Furthermore, it is possible that students have changed their perspective on format options since the pandemic when they were forced to complete a significant portion of their education in online or hybrid formats.

The purpose of this research study was to address the following questions in the context of survey data from students in a variety of different majors and academic plans who were enrolled in the first semester of a two-semester, systems-based combined anatomy and physiology course sequence, both prior to the COVID-19 pandemic and after.

Which form of presentation or discussion do students prefer when first introduced to new material that is conceptually difficult and does that differ for material that is not conceptually difficult?

Do students prefer whole group discussion, small group discussions or to work alone after having been presented material in class?

Do students prefer to have more hands-on time in the laboratory or do they prefer to spend time studying photographs of slides, specimens and anatomic models on their own?

Methods

Study Context and Participants

This project was conducted at Frostburg State University (FSU), a comprehensive, regional, public, liberal arts university in Western Maryland. FSU is part of the University System of Maryland (USM) and is the only four-year public institution in the state west of the Baltimore-Washington metropolitan area. It serves as the educational center for Western Maryland and surrounding counties in Pennsylvania and West Virginia and typically enrolls 4,700 to 5,000 undergraduate and graduate students each year.

In this study, students enrolled in human anatomy and physiology I (A&P I; the first of a two-semester, systems-based human anatomy and physiology course sequence) were surveyed at the beginning of the semester and just before completing the course in fall 2016 and fall 2017. All data from 2016 and 2017 were combined and analyzed as pre-pandemic results. Another survey with the same questions was given to students enrolled in the same A&P I course during the fall 2021 semester, after the pandemic when the university had returned to fully in-person instruction.

At FSU, students in several different majors and academic pathways take the A&P I course. The majors include biology, chemistry, health science (pre-medical, pre-dental, pre-physician assistant, pre-physical therapy), and exercise and sport science. Students with other academic plans include transfer students (pre-nursing, pre-dental hygiene, pre-occupational therapy), and other majors, such as psychology, or undecided students, who take the course for a variety of personal and academic reasons. There was a total of 306 students enrolled in A&P I at the beginning of the fall 2016 and 2017 semesters and 282 students completed the course with 24 student withdrawals. There was a total of 151 students enrolled in A&P I at the beginning of the fall 2021 semester and 127 students completed the course with 24 student withdrawals. The study was approved by the FSU Institutional Review Board prior to the surveys in 2016/2017 and again in 2021 (FSU Project #H2016-001 and #H2022-002, respectively) and informed consent was obtained from all participants. Student participation was voluntary and anonymous and had no influence on course grades.

Description of Survey Questions

All students in A&P I were asked to complete two in-person paper surveys (see Appendix). There was no time limit for either survey. The initial survey was done at the beginning of the semester during the second week of class, and the final survey was done near the end of the semester during the second-to-last week of class before final exams began and grades were finalized. Note that the final survey was completed after the course withdrawal deadline (week 10), meaning that students who withdrew from A&P I in 2016 and 2017 (n=24) and 2021 (n=24) were not represented. In 2016 and 2017, a total of 294 students completed the initial survey (96.1%) and a total of 248 students completed the final survey (87.9%). In 2021, a total of 123 students completed the initial survey (81.5%) and a total of 79 students completed the final survey (62.2%).

Students were asked which form of presentation or discussion they preferred when first introduced to new material that is not conceptually difficult. They could select lecture presentation, with or without PowerPoint or other multimedia presentations, whole group discussions, small group discussions, or they could choose to work on their own. A similar question with the same optional responses was asked with reference to material that is conceptually difficult. Students were also asked whether they preferred whole group discussion, small group discussion, or working alone after they have been afforded time to work with material presented to them or assigned to them in class.

Finally, students were asked if they would prefer to have more time to work with microscope slides, specimens and anatomical models in the laboratory or if they would prefer to spend time studying photographs of slides, specimens and models on their own. In the final survey, students were asked the same questions and were given the option to note that they had changed their opinion from the initial survey. Given that students may not have accurately recalled their answer to this question from the initial survey, responses to this question are not reported.
Data Analysis

Data from 2016 and 2017 were combined for statistical analyses for pre-pandemic results and data from 2021 were used for statistical analyses for post-pandemic results. Graphic results comparing initial and final survey data are reported as percentages to account for the reduced number of students completing the final survey each year and for the different number of student’s completing the surveys before and after the pandemic. Chi-square tests for independence were used to compare initial and final survey responses and to compare survey responses between the years before and after the pandemic. Significance was set at $p \leq 0.05$.

Results

On the question of what presentation format was preferred by students when first introduced to new material, students most frequently selected the Lecture with PowerPoint format whether the material was conceptually difficult or not (Figure 1). This is true for those completing the survey both prior to and after the COVID-19 pandemic.

On the surveys conducted before the pandemic, 77.9% of students on initial survey and 77.7% on final survey indicated a preference for Lecture with PowerPoint when presented with new, non-conceptual material. There was no significant change between initial and final surveys ($p = 0.98$) among those choosing Lecture with PowerPoint for non-conceptually difficult material. Among students completing the survey post-pandemic, similar numbers of students preferred the Lecture with PowerPoint format (73.5% on initial survey and 71.5% on final) for non-conceptual material. Again, there was no significant change between the initial and final surveys ($p = 0.78$).

Regarding new, conceptually difficult material, 51.4% of students on initial survey and 63.8% on final survey indicated a preference for Lecture with PowerPoint pre-pandemic (Figure 2). There was no significant change between the surveys ($p = 0.56$) in the numbers of students choosing this option. A higher number of students selected the Lecture with no PowerPoint format when presented with conceptually difficult material than did so for non-conceptual material preferring class discussions instead. Among students completing the survey post-pandemic, 60.6% preferred the Lecture with PowerPoint on initial survey while 58.0% of respondents did so on final survey with a greater number choosing small group discussions. Again, there was no significant change between the surveys ($p = 0.68$). In addition, there were no statistical differences between the pre-pandemic and post-pandemic surveys regarding student preference for the format of new material whether non-conceptual ($p = 0.74$) or conceptual ($p = 0.26$).

![Figure 1. Student preferences (pre- and post-pandemic) on form of presentation or discussion of new material that is not conceptually difficult expressed as percent of students completing initial and final surveys.](image-url)
When surveyed on their preference for whole group discussion, small group discussion or if they preferred to work alone after having time to work on assigned material (Figure 3), students surveyed pre-pandemic preferred small group discussion (43.9% on initial survey and 44.8% on final). There were no significant changes from initial to final surveys ($p = 0.77$). The number of those who preferred whole group discussion declined from 38.6% on initial survey to 32.3% on final survey prior to the pandemic although the change was not significant ($p = 0.36$).

In contrast, those surveyed post-pandemic preferred whole group discussion for the review of material (45.2% on initial survey and 46.7% on final). There were no significant changes from the initial to final surveys ($p = 0.62$) among those who preferred whole group discussion. Fewer students (35.7% on initial survey and 28.0% on final survey) noted a preference for small group discussion. This is also a non-significant change between initial and final surveys ($p = 0.27$) among those with a preference for small group discussion post-pandemic. However, there were significant changes from the pre-pandemic to post-pandemic choices with students in the post-pandemic group preferring whole group discussion ($p = 0.02$).
When asked if they preferred more time in the laboratory or would prefer to study alone (Figure 4), most students completing the surveys pre-pandemic preferred time in lab (66.4% on initial survey and 64.6% on final survey). Fewer students (33.6% on initial survey and 35.4% on final survey) indicated a preference for less time in the laboratory in exchange for more time to work alone. There were no significant changes from initial to final survey on the choice to work alone ($p = 0.65$) or among those choosing time in lab ($p = 0.81$) indicating students remained loyal to their preferences throughout the semester prior to the pandemic. The percentage of students who completed the survey post-pandemic indicating that they wished to study on their own increased considerably from 26.5% at the beginning of the semester to 36.5% on the final survey ($p = 0.01$). Again, overwhelmingly, students prefer time in the laboratory and hands-on study (73.5% on initial survey; 63.5% on final survey). There were no significant changes from initial to final survey among those with a preference for lab time in the post-pandemic group ($p = 0.44$).

**Discussion**

In the present study, students enrolled in a combined anatomy and physiology course, both prior to the COVID-19 pandemic and after, overwhelmingly preferred traditional lecture with PowerPoint presentation where they were provided notes in outline format. This was true whether the covered material was considered non-conceptual or conceptually difficult. This mode of presentation was preferred over lecture without provided notes and over whole-group or small-group discussions and over studying alone. This is consistent with a study published in 2021 by Vijay where a majority of undergraduate medical students had a preference for traditional modes of teaching, agreeing that it provided better understanding of concepts. Studies such as those conducted by Barnett (2003), Cornelius and Owen-DeSchryver (2008) and Raver and Maydosz (2010), found students performed better on exams when given partial notes compared to either full notes or no notes being provided. Furthermore, students receiving full notes also self-reported more negative effects on attendance (Cornelius and Owen-DeSchryver 2008). Perhaps students in this present study felt better prepared for or performed better on assessments by attending traditional lectures where partial notes were provided.

Noteworthy, too, is that when presented with new material considered conceptually difficult, a group discussion was a popular choice. The vast majority, however, preferred traditional lecture (with PowerPoint presentation). Small-group discussion was popular among students completing the survey pre-pandemic; meanwhile, whole-group discussion was preferred among students post-pandemic.

During the pandemic, our students, like most, were largely forced to continue their education online. Some disadvantages of online curricula may include lower levels of engagement with instructors, fellow students and the course material itself (Cowan et al. 2022; Pollock 2002; Wester 2021; Wilhelm et al. 2020). Multiple cohorts of medical students gave lower scores for the overall learning experience when surveyed about their online versus in-person versus education (Cowan et al. 2022). We can speculate that perhaps it is students’ lack of feeling engaged that was identified by the authors cited above that could account for the higher percentage of post-pandemic
students opting for small-group discussion on final survey in the present study. It could also account for a greater percentage of students in the post-pandemic cohort with a preference for whole-group discussion when asked if they prefer small-group or whole-group discussions or if they prefer to work alone after being presented with or assigned material in class.

On the question of whether students preferred more time in the laboratory or would prefer to study alone, the majority of students completing the survey pre-pandemic preferred lab time as did the post-pandemic cohort. Willingness to exchange time in lab for more time to study outside of class was popular with the post-pandemic cohort compared to those surveyed pre-pandemic.

Upon comparing student performance in anatomy and physiology between face-to-face, hybrid, and online A&P lab styles, Pollock published in 2022 that hybrid lab students reported better experiences and greater satisfaction, attended more labs, and outperformed online lab students. Face-to-face lab students, however, outperformed hybrid lab students. Yet another study conducted during the transition to emergency remote teaching found the prevalent challenges reported by anatomy students included those related to the loss of access to lab, including difficulty identifying and visualizing structures in three dimensions and the loss of context and sensorial cues (Wilhelm et al. 2020). In their survey of medical students’ perceptions on gross anatomy education in 2020, Liang and colleagues reported that among the various methods for laboratory instruction experienced, the only significant preference was that “no lab” was the least preferred by the overall class. Among 168 microbiology students surveyed by Joji et al (2022), 50.6% preferred face-to-face lab sessions compared to 30.4% who preferred online labs. Meanwhile, among the faculty, 85.7% preferred the face-to-face mode of teaching. On comparing students’ perceptions of face-to-face and online anatomy teaching, Potu et al (2022) found students to be in favor of face-to-face demonstrations for better understanding of the spatial orientation and the visualization of the anatomical relations between structures, understanding the difficult anatomical structures, understanding the clinical correlations, and making them more confident about their practical exams. However, students were in favor of online demonstrations for retaining key information, confidence levels on discussing anatomy learning needs, effective utilization of demonstration time, and lower stress associated with online learning. The majority of the students who participated in the survey preferred a mixture of both face-to-face and online anatomy demonstrations.

These studies explain our students’ preferences in this study for face-to-face laboratory instruction and may explain the greater desire of students in the post-pandemic cohort to exchange a portion of that lab time for study on their own. Online instruction during the pandemic likely revealed the importance of hands-on lab instruction and also, likely, resulted in students’ comfort with independent study and perhaps the use of technology to aid in their study. Anecdotally, we have observed students in the A&P lab utilizing smart phones and tablets to take pictures of specimens, models and histological slides to create images for labeling or using various virtual anatomy apps to supplement their review of the material.

Conclusions

This study reveals that the anatomy and physiology students surveyed before and after the pandemic preferred traditional modes of teaching, such as lecture where they are provided with notes in an outline format, over group discussions or working alone when being presented with new material, whether that material was conceptually difficult or not. Students also overwhelmingly preferred face-to-face time in anatomy lab instruction. However, there was a greater increase in the percentage of students after the pandemic who, by the end of the course, preferred to exchange some lab time for study on their own as compared to pre-pandemic numbers. This is likely due to developing a greater comfort in working independently during the pandemic. Increasing use of technology may also account for students’ preferences for giving up some lab time for study on their own. Since the pandemic there was also an increase in the percentage of students who prefer whole-group, in-class discussion to review material that was previously covered in class. Feelings of disengagement during remote instruction during the pandemic may account for this desire to study as a group.

Despite trends towards virtual instruction, traditional means of instruction remain popular and are indispensable, especially in a course such as anatomy and physiology where hard-to-understand physiology concepts are presented and where face-to-face, hands-on instruction is necessary to allow visualization of anatomic structures and their relationship to each other in three-dimensions. These kinesthetic activities have been shown to be important to many students in supporting their ability to learn (Keller and Hughes 2021; Pollock 2022). Other modes of instruction or presentation formats may have their advantages but care must be taken to limit their disadvantages such as lack of student engagement and motivation (Britson 2022; Cowan et al. 2022). We must remain cognizant of our students’ preferences in order to help keep them engaged in the extensive content of human anatomy and physiology courses.

continued on next page
A Comparison of Student Preferences for Presentation Format in an Undergraduate Human Anatomy and Physiology Course Before and After the Pandemic

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Literature Cited
https://doi.org/10.21692/haps.2022.010

continued on next page
Appendix 1: Initial and Final Surveys Given to Students in Fall of 2016, 2017 and 2021

Human Anatomy and Physiology Research Study Initial Questionnaire

We are interested in learning your initial perceptions about the presentation format of the material covered in the human anatomy and physiology course. With this in mind, we are asking you to complete the following questionnaire. Your participation is voluntary and will have no influence on class grades as all responses will be anonymous and class information will be kept confidential. If you choose to participate, please answer all of the following questions honestly. Do not put your name anywhere on this survey. If you have any questions about this questionnaire, please ask your instructor.

Instructions for Questions: Put an “X” by the correct option for each question. Please answer the questions as honestly as you can and choose the most appropriate answer to each question. Do not spend a long time on each question as your first reaction is probably your best answer.

1. Which form of presentation or discussion do you prefer when you are first introduced to new material that is somewhat easy to understand (not conceptually difficult)?
   ____ Lecture presentation (without PowerPoint or other multimedia presentations)
   ____ Lecture presentation (with PowerPoint or other multimedia presentations)
   ____ Whole group (entire class) discussion
   ____ Small group discussions
   ____ None of these choices; I prefer to work on my own by reading assigned material

2. Which form of presentation or discussion do you prefer when you are first introduced to new material that is conceptually difficult?
   ____ Lecture format (without PowerPoint or other multimedia presentations)
   ____ Lecture format (with PowerPoint or other multimedia presentations)
   ____ Whole group (entire class) discussion
   ____ Small group discussions
   ____ None of these choices; I prefer to work on my own by reading assigned material

3. After you have had time to work with material that was presented to you or assigned to you in class, which form of classroom engagement do you think is most helpful?
   ____ Whole group (entire class) discussion
   ____ Small group discussions
   ____ None of these choices; I prefer to work on my own

4. Would you prefer to have more time to work with microscope slides, specimens and models in the laboratory or would you prefer to spend time studying photos of the slides, specimens and models on your own?
   ____ Additional time studying slides, specimens and models in the laboratory is more beneficial
   ____ Studying photos on my own time is more beneficial

Thank you for your participation! Drs. Keller and Hughes
Human Anatomy and Physiology Research Study Final Questionnaire

Now that you have almost completed the Human Anatomy and Physiology class, we are interested in learning whether your initial perceptions regarding the presentation format of the material covered in the Human Anatomy and Physiology course have changed. We are asking you to complete a final questionnaire. As before, your participation is voluntary and will have no influence on class grades as all responses will be anonymous and class information will be kept confidential. If you choose to participate, please answer all of the following questions honestly. Do not put your name anywhere on this survey. If you have any questions about this questionnaire, please ask your instructor.

**Instructions for Questions:** Put an “X” by the correct option for each question. Please answer the questions as honestly as you can and choose the most appropriate answer to each question. Do not spend a long time on each question as your first reaction is probably your best answer.

1. Which form of presentation or discussion do you prefer when you are first introduced to new material that is somewhat easy to understand (not conceptually difficult)? (If you have changed your opinion on this question, put an “X” on the first line in addition to your current choice.)
   - ___ I have changed my opinion on this question
   - ___ Lecture presentation (without PowerPoint or other multimedia presentations)
   - ___ Lecture presentation (with PowerPoint or other multimedia presentations)
   - ___ Whole group (entire class) discussion
   - ___ Small group discussions
   - ___ None of these choices—I prefer to work on my own by reading assigned material

2. Which form of presentation or discussion do you prefer when you are first introduced to new material that is conceptually difficult? (If you have changed your opinion on this question, put an “X” on the first line in addition to your current choice.)
   - ___ I have changed my opinion on this question
   - ___ Lecture format (without PowerPoint or other multimedia presentations)
   - ___ Lecture format (with PowerPoint or other multimedia presentations)
   - ___ Whole group (entire class) discussion
   - ___ Small group discussions
   - ___ None of these choices—I prefer to work on my own by reading assigned material

3. After you have had time to work with material that was presented to you or assigned to you in class, which form of classroom engagement do you think is most helpful? (If you have changed your opinion on this question, put an “X” on the first line in addition to your current choice.)
   - ___ I have changed my opinion on this question
   - ___ Whole group (entire class) discussion
   - ___ Small group discussions
   - ___ None of these choices—I prefer to work on my own

4. Do you think you benefitted more from working with microscope slides, specimens and models in the laboratory or spending time studying photos of the slides, specimens and models on your own? (If you changed your opinion on this question, put an “X” on the first line in addition to your current choice.)
   - ___ I have changed my opinion on this question
   - ___ Additional time studying slides, specimens and models in the laboratory is more beneficial
   - ___ Studying photos on my own time is more beneficial

Thank you for your participation! Drs. Keller and Hughes
Assessment of Motivation in Human Anatomy and Physiology Students

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Abstract
Motivation is one of the keys to success in challenging courses such as human anatomy and physiology (A&P) and may occur in the form of intrinsic motivation (IM, motivation for enjoyment), extrinsic motivation (EM, motivation for reward), and/or amotivation (AM, lack of motivation). The goal of this study was to identify ways of supporting student success in A&P by identifying sources of motivation correlated with increased performance and determining if motivational efforts change. Three surveys, including the Motivated Strategies for Learning Questionnaire developed by Pintrich in 1990, were administered to students enrolled in A&P I at the University of Mississippi during the fall semester of 2021. Relevant survey questions were categorized to source of motivation and summed motivation scores for each student were analyzed for correlations with student performance on major assessments in the course. EM was not correlated with any assessment score while AM (assessed only on the second survey) was negatively correlated with all assessment scores. IM scores from survey 1 were not correlated with any assessment score. IM scores from survey 2 were positively correlated with exam 1 and 4 scores as well as the total earned course score. IM scores from survey 3 were positively correlated with all assessment scores. For students accustomed to the rewards from EM, IM may be a latent variable that is only accessed by the individual when needed. Further, educators can promote student achievement by guiding students to identify and use IM early and consistently throughout the course. https://doi.org/10.21692/haps.2022.021

Key words: motivation, MSLQ, anatomy, physiology, human, education, performance

Introduction
Human anatomy and physiology (A&P) can be a difficult and daunting course for college students and has a high DFW rate (letter grade of D, F, or withdrawal from the course; Sturges et al. 2016). This could be due to large, complicated amounts of information to learn and understand, or the pressure to succeed in order to continue with a student’s program and career goal (Meguid et al. 2019). A&P requires demonstrated knowledge of organs, tissues, and body functions and an ability to learn and understand intricate details about the human body. Studies suggest that learning outcomes in anatomy education are not covered heavily enough, thus increasing the burden for students to participate in self-directed learning in order to cover topics (Meguid et al. 2019). This could be attributed to the fact that there are so many topics to cover, making it hard to spend large amounts of time on any one learning outcome. Maurer et al. (2013) stated (without providing data) that up to 50% of students enrolled in their A&P courses fail to earn at least a C, and must either retake the course, change their major, or drop out. Published reports with data on the success rate (e.g., at least a C or better) in A&P I range from a low of 36% (Abdullahi and Gannon 2012) to a high of 73% (Young et al. 2019). The average success rate internally at the University of Mississippi and across published reports is approximately 61% (Britton 2022) with data from over 16,000 students.

Succeeding in an A&P course requires, in part, motivation, and this manuscript explores students’ motivational efforts and how they impact academic habits and performance. Deci and Ryan’s (1985) self-determination theory (SDT) does not define motivation as a unitary concept (Maurer et al. 2013), but divides motivation into three types: intrinsic motivation (IM), extrinsic motivation (EM), and amotivation (AM). IM is the “most self-determined type of motivation, in which activities are accomplished for the sake of enjoyment” (Sturges et al. 2016). IM can further be divided into three subscales: IM to know, IM toward accomplishments, and IM to experience stimulation (Vallerand et al. 1992). IM to know is when an individual engages in a behavior for the pleasure experienced while trying to accomplish a task or create something; IM to experience stimulation occurs when an individual experiences fulfillment when learning or understanding something new. IM toward accomplishments “occurs when an individual engages in a behavior for the pleasure experienced while trying to accomplish a task or create something.” IM to experience stimulation occurs when an individual participates in something to allow “stimulating or exciting sensations” (Vallerand et al. 1992). IM is not motivated by any type of reward, just for the success of learning and enjoyment.

EM is when a behavior is driven by a reward or incentive beyond the actual task. EM is further divided into three subscales: EM identified, EM introjected, and EM external (Sturges et al. 2016). EM identified occurs when someone
values the result of the task, though they do not enjoy doing it. EM introjected occurs when someone only participates in the undertaking “to maintain personal expectations or avoid guilt.” EM external occurs when someone only participates in a task “solely as a means to obtain an external reward or avoid punishment” (Sturges et al. 2016). The rewards involved in EM pertaining to A&P may be a good grade in the course or on an exam, entry into a professional school, etc. AM is at the opposite end of the self-determination theory from being intrinsically motivated, where motivation is lacking completely.

Studies show that students are shifting from an intrinsic to extrinsic motivational approach in A&P courses (Sturges et al. 2016) and that “instructors can influence students’ motivation on the extrinsic motivation subscales through an attendance policy, in-class assignments and other activities, but have little control over a students’ intrinsic motivation” (Maurer et al. 2013). However, “students whose motivations are more intrinsic do better in school, have lower rates of withdrawal, absenteeism, and dropout, and have lower feelings of anxiety about school with higher levels of academic performance” (Sturges et al. 2016). Griffin et al. (2013) showed that the leading factor in advancement of overall academic performance is a student’s level of intrinsic motivation. Botnaru et al. (2021) further researched the link between academic motivation and performance in undergraduates enrolled in general chemistry, organic chemistry, and anatomy and physiology. Their results suggested that students in lower-level STEM courses reported relatively high levels of motivation that remained stable over time. However, there still exists a relative lack of research on motivation in lower-level STEM courses, particularly A&P (Britson 2022) and student outcomes, leading to this study on identifying the impact of the intrinsic motivations on performance by A&P students.

This study focuses on students enrolled in human anatomy and physiology I at the University of Mississippi. A&P is a requirement for many science majors and a pre-requisite for many professional schools, so most students in the course are enrolled in a pre-health major and are interested in a future in the healthcare field. We want to determine when or if motivational efforts change during the semester and identify how to better develop intrinsic motivation in students. We will also explore possible relationships between demographics (e.g., race, gender, year in school, and/or cultural background) and motivation. We hypothesize that students’ motivational efforts will correlate with their final class scores, and that increased motivation leads to higher grades and academic success.

### Materials and Methods

Students (n = 276) enrolled in human anatomy and physiology I (A&P I) during the Fall 2021 semester at the University of Mississippi were recruited to participate in this study. BISC 206 is the first semester course of a two-semester sequence and focuses on the structure and function of cells, tissues, and the integumentary, skeletal, muscular, and nervous systems within the human body. Human Anatomy and Physiology Society Learning Outcome Modules A through H (Body Plans through Nervous System; HAPS 2019) were used in course design and assessment selection. There was one lecture section that met three times a week for 50 minutes per session plus 10 to 13 laboratory sections that met once a week for two hours (additional background information on the course structure can be found in Britson 2022). All lecture and laboratory sessions in the Fall 2021 semester were held in-person. This protocol was approved as exempt under 45 CFR 46.101(b) (#2) by the University of Mississippi Institutional Review Board (Protocol #21x-262).

Three optional surveys were administered to students enrolled in A&P I at intervals throughout the semester. Each survey was conducted during the students’ laboratory session and took 10-15 minutes to complete. Each student who completed a survey was required to sign a consent form to grant access to survey responses and de-identified final course scores. Survey questions asked participants to respond to each statement on a Likert scale (Fowler 2009) from “strongly disagree” to “strongly agree.” Specific dates to administer the surveys were chosen to assess motivational thoughts and efforts at the beginning of the semester, mid-semester, and end of the semester.

The first survey was administered during the second week of the semester. Survey 1 contained optional demographic questions, (e.g., age, sex, year in school, GPA, cultural background, and major) in addition to questions specific to A&P I (Table 1) and students’ thoughts and goals for their academic performance throughout the upcoming semester (i.e., future tense was used in the questions). The second survey (Table 2) was administered during 28-30 September 2021, which was just before the week of the first lab practical and the middle of the semester. Survey 2 was a standardized survey with questions adapted from the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al. 1990) and used the present tense. The third survey (Table 3) was administered during 16-18 November 2021, the week before the Thanksgiving holidays and three weeks before final examinations that would mark the end of the semester. Survey 3 included questions similar to survey 1 but evaluated students’ thoughts towards their course performance after having almost completed the course (i.e., past tense was used in questions).
## Table 1.

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>strongly disagree (1)</th>
<th>disagree (2)</th>
<th>neutral (3)</th>
<th>agree (4)</th>
<th>strongly agree (5)</th>
<th>N</th>
<th>mean score ± SD</th>
<th>Source of Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think I will make a good grade in this class.</td>
<td>0</td>
<td>1</td>
<td>48</td>
<td>122</td>
<td>43</td>
<td>214</td>
<td>3.98 ± 0.67</td>
<td></td>
</tr>
<tr>
<td>I will work hard to do well even if I do not enjoy the material being taught.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>64</td>
<td>148</td>
<td>213</td>
<td>4.69 ± 0.47</td>
<td>EM identified</td>
</tr>
<tr>
<td>I will try my hardest to attend every lecture.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>40</td>
<td>171</td>
<td>212</td>
<td>4.80 ± 0.41</td>
<td></td>
</tr>
<tr>
<td>I am only taking this course because it is required for my major/post-college career.</td>
<td>11</td>
<td>42</td>
<td>55</td>
<td>60</td>
<td>45</td>
<td>213</td>
<td>3.41 ± 1.17</td>
<td>EM external</td>
</tr>
<tr>
<td>I will spend as much time as it takes to understand the material being taught.</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>96</td>
<td>111</td>
<td>214</td>
<td>4.49 ± 0.56</td>
<td>IM accomplishments</td>
</tr>
<tr>
<td>I will work hard to get a good grade even if I do not enjoy the material being taught.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>58</td>
<td>147</td>
<td>206</td>
<td>4.71 ± 0.46</td>
<td>EM external</td>
</tr>
<tr>
<td>I will complete practice questions and review assignments to study for exams.</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>74</td>
<td>129</td>
<td>206</td>
<td>4.62 ± 0.52</td>
<td>EM identified</td>
</tr>
<tr>
<td>It is important to me that I learn and understand the material I am being taught in class.</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>46</td>
<td>159</td>
<td>206</td>
<td>4.77 ± 0.43</td>
<td>IM know</td>
</tr>
<tr>
<td>I will be an active learner and ask questions when I need to.</td>
<td>0</td>
<td>1</td>
<td>19</td>
<td>76</td>
<td>112</td>
<td>208</td>
<td>4.44 ± 0.68</td>
<td>IM know</td>
</tr>
<tr>
<td>I am taking this class for the pleasure that I experience in broadening my knowledge about subjects which appeal to me.</td>
<td>1</td>
<td>15</td>
<td>76</td>
<td>70</td>
<td>40</td>
<td>202</td>
<td>3.66 ± 0.89</td>
<td>IM know</td>
</tr>
</tbody>
</table>

Note: Categorization to source of motivation is listed for relevant survey questions (EM = extrinsic motivation, IM = intrinsic motivation).
<table>
<thead>
<tr>
<th>Survey Question</th>
<th>strongly disagree (1)</th>
<th>disagree (2)</th>
<th>neutral (3)</th>
<th>agree (4)</th>
<th>strongly agree (5)</th>
<th>N</th>
<th>mean score ± SD</th>
<th>Source of Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have made good grades in this class thus far.</td>
<td>2</td>
<td>30</td>
<td>73</td>
<td>83</td>
<td>13</td>
<td>201</td>
<td>3.38 ± 0.85</td>
<td>EM identified</td>
</tr>
<tr>
<td>I do not really enjoy the material being taught, but I am still studying hard in order to do well in the class.</td>
<td>10</td>
<td>77</td>
<td>62</td>
<td>44</td>
<td>9</td>
<td>202</td>
<td>2.82 ± 0.97</td>
<td>EM identified</td>
</tr>
<tr>
<td>I have attended lecture and paid attention.</td>
<td>2</td>
<td>3</td>
<td>25</td>
<td>92</td>
<td>79</td>
<td>201</td>
<td>4.21 ± 0.79</td>
<td>EM identified</td>
</tr>
<tr>
<td>I have given myself enough time to prepare for the exam, so that I don’t have to cram.</td>
<td>6</td>
<td>23</td>
<td>68</td>
<td>78</td>
<td>27</td>
<td>202</td>
<td>3.49 ± 0.96</td>
<td>EM identified</td>
</tr>
<tr>
<td>I am spending as much time as needed in order to learn and understand the material.</td>
<td>2</td>
<td>19</td>
<td>56</td>
<td>93</td>
<td>32</td>
<td>202</td>
<td>3.66 ± 0.89</td>
<td>IM know</td>
</tr>
<tr>
<td>This material is too difficult. I do not feel motivated to study if I cannot understand.</td>
<td>13</td>
<td>100</td>
<td>55</td>
<td>30</td>
<td>6</td>
<td>204</td>
<td>2.59 ± 0.92</td>
<td>Amotivation</td>
</tr>
<tr>
<td>I have utilized my resources (practice questions, reading the textbook, reviewing quizzes, office hours) to learn the information being taught.</td>
<td>1</td>
<td>7</td>
<td>37</td>
<td>116</td>
<td>31</td>
<td>192</td>
<td>3.88 ± 0.73</td>
<td>IM know</td>
</tr>
<tr>
<td>I am learning and understanding the material, not just memorizing it.</td>
<td>0</td>
<td>18</td>
<td>61</td>
<td>103</td>
<td>10</td>
<td>192</td>
<td>3.55 ± 0.73</td>
<td>IM know</td>
</tr>
<tr>
<td>I am an active learner and ask questions when I need to.</td>
<td>5</td>
<td>37</td>
<td>74</td>
<td>67</td>
<td>11</td>
<td>194</td>
<td>3.21 ± 0.90</td>
<td>IM know</td>
</tr>
<tr>
<td>I am glad I am taking this class.</td>
<td>5</td>
<td>14</td>
<td>65</td>
<td>80</td>
<td>28</td>
<td>192</td>
<td>3.59 ± 0.92</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Frequency, mean, and standard deviation of human anatomy and physiology I student responses to survey 2. Categorization to source of motivation is listed for relevant survey questions (EM = extrinsic motivation, IM = intrinsic motivation).
### Table 3

Frequency, mean, and standard deviation of human anatomy and physiology I student responses to survey 3. Categorization to source of motivation is listed for relevant survey questions (EM = extrinsic motivation, IM = intrinsic motivation).

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>strongly disagree (1)</th>
<th>disagree (2)</th>
<th>neutral (3)</th>
<th>agree (4)</th>
<th>strongly agree (5)</th>
<th>N</th>
<th>mean score ± SD</th>
<th>Source of Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am going to make a good grade in this class.</td>
<td>7</td>
<td>24</td>
<td>61</td>
<td>61</td>
<td>17</td>
<td>170</td>
<td>3.33 ± 0.98</td>
<td></td>
</tr>
<tr>
<td>I worked as hard as I could to understand the material being taught.</td>
<td>0</td>
<td>8</td>
<td>36</td>
<td>80</td>
<td>45</td>
<td>169</td>
<td>3.95 ± 0.83</td>
<td>IM accomplishments</td>
</tr>
<tr>
<td>I attended lectures and paid attention throughout.</td>
<td>1</td>
<td>10</td>
<td>31</td>
<td>88</td>
<td>39</td>
<td>169</td>
<td>3.92 ± 0.84</td>
<td>IM know</td>
</tr>
<tr>
<td>I wish that I had put more effort into this course.</td>
<td>4</td>
<td>30</td>
<td>50</td>
<td>64</td>
<td>22</td>
<td>170</td>
<td>3.42 ± 1.00</td>
<td>EM identified</td>
</tr>
<tr>
<td>I spent as much time as needed to understand the material.</td>
<td>3</td>
<td>19</td>
<td>70</td>
<td>60</td>
<td>18</td>
<td>170</td>
<td>3.42 ± 0.89</td>
<td>IM know</td>
</tr>
<tr>
<td>I worked as hard as I could to get a good grade in the course.</td>
<td>0</td>
<td>9</td>
<td>50</td>
<td>66</td>
<td>41</td>
<td>166</td>
<td>3.83 ± 0.86</td>
<td>EM external</td>
</tr>
<tr>
<td>I completed practice questions, read the textbook, reviewed quizzes, and attended office hours to better learn the material.</td>
<td>2</td>
<td>19</td>
<td>50</td>
<td>64</td>
<td>31</td>
<td>166</td>
<td>3.62 ± 0.95</td>
<td>IM know</td>
</tr>
<tr>
<td>I enjoyed learning about A&amp;P and feel confident in my knowledge of it.</td>
<td>4</td>
<td>22</td>
<td>70</td>
<td>48</td>
<td>22</td>
<td>166</td>
<td>3.37 ± 0.95</td>
<td>IM accomplishments</td>
</tr>
<tr>
<td>I would recommend this course to other students.</td>
<td>12</td>
<td>32</td>
<td>68</td>
<td>36</td>
<td>18</td>
<td>166</td>
<td>3.10 ± 1.06</td>
<td></td>
</tr>
<tr>
<td>I am glad I took this course.</td>
<td>9</td>
<td>17</td>
<td>61</td>
<td>46</td>
<td>32</td>
<td>165</td>
<td>3.46 ± 1.08</td>
<td></td>
</tr>
</tbody>
</table>
Survey responses were given numerical values on a scale of 1-5 for the corresponding responses of Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree respectively. Where relevant, survey questions were categorized to source of motivation [Internal Motivation (IM), Amotivation (AM), or External Motivation (EM), Tables 1-3; Sturges et al. 2016]. Summed motivation scores for each student were then analyzed via Pearson correlation tests for each pair wise comparison of motivation scores, exam scores, lab practical scores, and course average. The level of significance was set at alpha = 0.01. Post-hoc, power analysis using G*Power Statistical Software (Faul et al. 2007) for correlation analyses at this level of significance yielded a power of 0.99 or greater for sample sizes of at least 85. Effect sizes of significant correlations were categorized at small (0.1 to 0.3), medium (0.3 to 0.5), or large (0.5 or greater; Cohen 1988). Frequency data and descriptive statistics were calculated for all survey questions. All statistical tests were conducted using SPSSV27 software licensed to the University of Mississippi.

**Results**

Demographic information was requested on survey 1, and students were given the option to share their age, sex, year in school, GPA, cultural background, and major. Of those, 159 shared their gender, with 85.5% female and 14.5% male. 165 students shared their year in school, with 3.6% in first year, 52.1% in second year, 30.9% in third year, 12.1% in fourth year, and 1.2% in fifth year or doing post-undergraduate studies. 14 students were first-generation college students. 28 students identified as ethnic majorities while 12 students identified as ethnic minorities and 6 students were gender minorities. 125 students provided their college majors, with the most common majors including exercise science, allied health studies, and dietetics and nutrition (Fig. 1). Mean, raw exam scores and earned course scores for students who participated in the surveys are shown in Table 4. Raw scores for exam and lab practical scores were normalized to an average of 75 using a z-score transformation (Winter, 2002) due to particularly low scores prior to calculating the student’s earned score for the course. The earned course score incorporates 2 lab practical scores, online homework, in-lab assessments, and extra credit points.

| Exam    | Score%
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exam 1</td>
<td>60.8</td>
</tr>
<tr>
<td>Exam 2</td>
<td>52.3</td>
</tr>
<tr>
<td>Exam 3</td>
<td>53.4</td>
</tr>
<tr>
<td>Exam 4</td>
<td>49.7</td>
</tr>
<tr>
<td>Exam 5</td>
<td>44.2</td>
</tr>
<tr>
<td>Earned course score</td>
<td>77.0</td>
</tr>
</tbody>
</table>

**Table 4.** Mean exam scores (%) and earned course score (%) of participating students in human anatomy and physiology 1.

![Figure 1. Program majors of students enrolled in BISC 206 in fall of 2021.](image)
Assessment of Motivation in Human Anatomy and Physiology Students

Survey 1 consisted of 10 questions that aimed to evaluate student motivation at the start of the course and before the first exam using a Likert scale. When the total extrinsic (Table 5) and intrinsic motivation scores (Table 6) from survey 1 were analyzed for correlations with performance on the lecture exams, lab practical exams, earned course score, and self-reported GPA, no significant relationships were identified.

<table>
<thead>
<tr>
<th></th>
<th>Earned course score</th>
<th>Exam 1 score, raw</th>
<th>Exam 2 score, raw</th>
<th>Exam 3 score, raw</th>
<th>Exam 4 score, raw</th>
<th>Exam 5 score, raw</th>
<th>Lab practical 1 score, raw</th>
<th>Lab practical 2 score, raw</th>
<th>GPA</th>
<th>Survey 1, total extrinsic motivation score</th>
<th>Survey 2, total extrinsic motivation score</th>
<th>Survey 3, total extrinsic motivation score</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPA</td>
<td>Pearson Correlation</td>
<td>0.49</td>
<td>0.385</td>
<td>0.344</td>
<td>0.362</td>
<td>0.359</td>
<td>0.375</td>
<td>0.225</td>
<td>0.324</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.025</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amotivation total</td>
<td>Pearson Correlation</td>
<td>-0.291</td>
<td>-0.267</td>
<td>-0.237</td>
<td>-0.265</td>
<td>-0.291</td>
<td>-0.211</td>
<td>-0.275</td>
<td>-0.223</td>
<td>0.041</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.000</td>
<td>0.002</td>
<td>0.000</td>
<td>0.001</td>
<td>0.697</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>203</td>
<td>204</td>
<td>204</td>
<td>203</td>
<td>92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey 1, total extrinsic motivation score</td>
<td>Pearson Correlation</td>
<td>-0.045</td>
<td>-0.005</td>
<td>-0.063</td>
<td>-0.006</td>
<td>0.042</td>
<td>-0.015</td>
<td>-0.028</td>
<td>-0.015</td>
<td>0.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.515</td>
<td>0.939</td>
<td>0.367</td>
<td>0.931</td>
<td>0.550</td>
<td>0.829</td>
<td>0.692</td>
<td>0.827</td>
<td>0.593</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>208</td>
<td>208</td>
<td>208</td>
<td>207</td>
<td>207</td>
<td>207</td>
<td>208</td>
<td>92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survey 2, total extrinsic motivation score</td>
<td>Pearson Correlation</td>
<td>-0.028</td>
<td>-0.083</td>
<td>-0.083</td>
<td>-0.128</td>
<td>-0.037</td>
<td>-0.021</td>
<td>-0.108</td>
<td>-0.021</td>
<td>0.000</td>
<td>0.217</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.695</td>
<td>0.237</td>
<td>0.236</td>
<td>0.069</td>
<td>0.603</td>
<td>0.768</td>
<td>0.123</td>
<td>0.762</td>
<td>0.999</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>204</td>
<td>204</td>
<td>204</td>
<td>203</td>
<td>203</td>
<td>204</td>
<td>204</td>
<td>203</td>
<td>204</td>
<td></td>
<td>92</td>
</tr>
<tr>
<td>Survey 3, total extrinsic motivation score</td>
<td>Pearson Correlation</td>
<td>-0.114</td>
<td>-0.048</td>
<td>-0.116</td>
<td>-0.098</td>
<td>-0.087</td>
<td>-0.129</td>
<td>-0.079</td>
<td>-0.138</td>
<td>0.079</td>
<td>0.091</td>
<td>-0.401</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.142</td>
<td>0.535</td>
<td>0.135</td>
<td>0.208</td>
<td>0.266</td>
<td>0.097</td>
<td>0.307</td>
<td>0.075</td>
<td>0.503</td>
<td>0.251</td>
<td>0.608</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>167</td>
<td>75</td>
<td>160</td>
<td>157</td>
<td></td>
</tr>
<tr>
<td>Extrinsic motivation total</td>
<td>Pearson Correlation</td>
<td>-0.056</td>
<td>-0.034</td>
<td>-0.134</td>
<td>-0.105</td>
<td>-0.047</td>
<td>-0.054</td>
<td>-0.152</td>
<td>-0.107</td>
<td>-0.024</td>
<td>0.791</td>
<td>0.641</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>0.498</td>
<td>0.682</td>
<td>0.103</td>
<td>0.199</td>
<td>0.568</td>
<td>0.513</td>
<td>0.063</td>
<td>0.193</td>
<td>0.843</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>68</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 5. Pearson correlation coefficients (r) for external motivation scores, amotivation scores, and course performance for students enrolled in human anatomy and physiology I. Correlation coefficients that exceed ± 0.5 (a large effect size) for a significant (p<0.01) correlation are in bold, and correlation coefficients that are between ± 0.3 to 0.5 (a medium effect size) or ± 0.1 to 0.3 (a small effect size) for a significant (p<0.01) correlation are in italics. Correlations on the diagonal are not depicted.
### Table 6.

Pearson correlation coefficients (r) for internal motivation scores and course performance for students enrolled in human anatomy and physiology I. Correlation coefficients that exceed ±0.5 (a large effect size) for a significant (p<0.01) correlation are in bold, and correlation coefficients that are between ±0.3 to 0.5 (a medium effect size) or ±0.1 to 0.3 (a small effect size) for a significant (p<0.01) correlation are in italics. Correlations on the diagonal are not depicted.
Survey 2 consisted of 10 questions that were standard to the Motivated Strategies for Learning Questionnaire (Pintrich et al. 1990). It was administered in between exam 2 and the first lab practical. Amotivation scores from question 6 (Table 2) were negatively correlated with all course performance variables but not self-reported GPA. Total extrinsic motivation scores from survey 2 were not correlated with any performance variable (Table 5), while total intrinsic motivation scores were positively correlated with exam 1 and exam 4 performance as well as earned course score (Table 6).

Survey 3 was administered to students one week after taking exam 4 and consisted of 10 questions that were similar to the questions asked in survey 1. Total extrinsic motivation scores from survey 3 were not correlated with any performance variable (Table 5), while total intrinsic motivation scores were positively correlated with all performance variables excluding self-reported GPA. The total extrinsic motivation scores from surveys 1, 2, and 3 combined were not significantly correlated with any performance variable (Table 5). The total intrinsic motivation scores from surveys 1, 2, and 3 combined were significantly correlated with exam 1 and exam 4 performance as well as earned course score (Table 6).

Across all three surveys, the mean response per question often declined from survey 1 to survey 3 for identical questions. For example, question 1 of each survey gauged the student’s confidence in their grade throughout the course. 3.98 was the mean response to this question for survey 1, 3.38 for survey 2, and 3.33 for survey 3 where 2 correlates to a response of “disagree”, 3 correlates to “neutral”, and 4 correlates to “agree” (Fig. 2). Question 2 across all surveys gauged the student’s motivations to work hard in the course. 4.69 was the mean response for survey 1, 2.82 for survey 2, and 3.95 for survey 3. Question 3 across all surveys asked if students were attending lecture and paying attention. 4.81 was the mean response for survey 1, 4.21 for survey 2, and 3.92 for survey 3.

**Figure 2.** Student responses to question 1 on surveys 1-3. Survey 1: “I think I will make a good grade in this class.” Survey 2: “I have made good grades in this class thus far.” Survey 3: “I am going to make a good grade in this class.”
Discussion

In a 2021 study on academic performance and motivation in undergraduate students enrolled in general chemistry, organic chemistry, and A&P, Botnaru and colleagues found that students in lower-level STEM courses reported relatively high levels of motivation that remained stable over time. Direct observation of students in A&P, however, suggests that motivation levels are not consistent throughout a course. The goal of this study was to examine levels of motivation across a semester and identify significant correlations of different types of motivation to student success. By identifying when, if at all, motivation levels change, we and other A&P instructors would be more enabled to identify and support motivations, particularly internal motivations, in our students, with the ultimate goal of helping students succeed in human anatomy and physiology.

Two general themes emerged from the survey results. First, internal motivation rather than external motivation was highly correlated with student success in the course. Second, scores for both internal and external motivation decreased over the course of the semester. Amotivation was only measured on the second survey and while negatively correlated with assessment performance, changes in motivation could not be assessed over time. Results for amotivation are included in the present study because questions on the second survey were taken directly from the standard MSLQ (Pintrich et al. 1990) and may be useful in comparison studies.

The first survey was administered during the second week of the semester to assess motivation levels before the first major assessment, exam 1. Average student response to question 10, “I am taking this class for the pleasure that I experience in broadening my knowledge about subjects which appeal to me” was higher than the mean response to question 4, “I am only taking this course because it is required for my major/post-college career.” This suggests that students felt more intrinsically motivated at the beginning of the semester, wanting to succeed in the course for the enjoyment and not the reward. However, neither the total internal nor external motivation scores from the first survey were correlated with exam 1 performance.

Internal motivation scores from survey 2 (administered after the second exam and before the first lab practical) were positively correlated with several assessments (exams 1 and 4 as well as the earned course score) and the internal motivation scores from survey 1. From the third survey, internal motivation scores were positively correlated with performance on all major assessments as well as the earned course score and internal motivation scores from the first and second surveys. Given that no source of motivation was correlated with self-reported GPA, students may have perceived that those rewards previously received via external motivation as routine. External motivation, while easy to provide, did not lead to increased learning and student performance. Further studies are needed to determine if internal motivation is a latent variable that is only identified and accessed by the individual when other sources of motivation are unproductive.

The second survey was administered just prior to mid-term and data showed that students were still motivated to work hard and succeed, but their mean responses were lower than on survey 1. For example, question 3 stated, “I have attended lecture and paid attention”, which received a mean score of 4.21, but on the first survey this question received a mean score of 4.80. Self-reported attendance in lecture seemed to decline, and so did students’ desire to spend as much time as needed to understand the material. Actual lecture attendance was recorded by the instructor via personal response systems (Britton 2022). Students averaged a low score of 2.82 on the statement, “I do not really enjoy the material being taught, but I am still studying hard in order to do well in the class,” and a score of 2.59 on the statement, “This material is too difficult. I do not feel motivated to study if I cannot understand.” These results seem to counteract each other, as the first points to students not studying hard in order to do well, and the second statement points to students disagreeing that they do not feel motivated to study.

The third survey was administered three weeks before the end of the semester, and after students had taken 4 exams. From exam 1 to exam 4, average test scores decreased (Table 1) and the mean response scores on the survey also decreased (as compared to responses from surveys 1 and 2). None of the statements on survey 3 received a mean score of 4 or higher. The statement, “I attended lectures and paid attention throughout” received an average score of 3.92, which is lower than the scores on the first two surveys and shows a decrease in self-reported class participation and attendance. Students also were less likely to believe that they would make a good grade in the course, with the average score for this statement being 3.33. At the end of the course students were neutral in their feelings about being glad they took human anatomy and physiology.

These data point to a decrease in motivation throughout the semester, as exam scores also similarly declined. Studies comparable to the present study found similar results. In Young et al. (2018), motivation was surveyed in students across 41 foundational STEM courses at the beginning and end of each semester in an academic year at a small primarily undergraduate university. They found significant pre- to post-semester declines in five measured motivational factors: intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation (Young et al. 2018). Zusho et al. (2003) investigated the levels of motivation in 458 students enrolled in introductory college chemistry classes. Overall, they found that students’ levels
of motivation decreased over time, students’ judgements of their confidence to do well in the class decreased, and students were less likely to believe that chemistry was important or useful to them (Zusho et al. 2003).

Similarly, coinciding declines in exam and motivation scores in the present study support the statement of Young et al. (2018) that “supporting student motivation…would lead to higher achievement”. Offering such support is critical because students’ confidence levels decrease if they receive negative feedback in the form of low assessment scores about their course performance (Zusho et al. 2003). It is essential for instructors to communicate to students the importance of maintaining internal motivation to succeed in the course rather than relying on external motivation or avoiding amotivation. Human anatomy and physiology are learnable and positive results are achievable if the student identifies and maintains, with the instructors’ guidance and support, their source of internal motivation and puts in the work necessary for success. Zusho et al. 2003 suggested that instructors convey to their students strategies or ways of thinking to better learn the material and encourage students to share with each other how they better learn the material.

A study by Ferland et al. (2022) assessed motivation in a statistics course and also found motivational declines across the semester. In an effort to avoid this decline, they incorporated “statistics in the news” where students brought in articles that could relate to what they were learning. This activity encouraged students to make a connection between the course material and their own lives (Ferland et al. 2022). A similar research project could be beneficial for Human anatomy and physiology courses and instructors. Relating the material to students’ lives might help them identify, develop, and maintain their internal motivation for success. Supporting internal motivation may also be one of several outcomes of efforts to promote diversity, equity, and inclusion, particularly a sense of belonging and self-identity as a scientist (Kalender et al. 2019), in the human anatomy and physiology classroom and can promote increases in exam and final course scores for students.

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Assessment of Motivation in Human Anatomy and Physiology Students


Tumescence in Cadaveric Dissection: A Teaching Perspective

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Abstract
Tumescence in cadaveric dissection involves the introduction of fluid into interstitial spaces to assist in the separation of natural tissue planes and the preservation of delicate structures. With a hand surgeon’s perspective, the senior author brought this technique into the cadaver lab. The infusion helped transform desiccated and adherent tissue into hydrated, mobile tissue, more like that of a living person. The use of the technique is described for dissecting the palms and soles, and the resulting dissections are demonstrated. https://doi.org/10.21692/haps.2022.005

Key words: tumescence, anatomy, cadaveric dissection, dissection facilitation

Introduction
Having used tumescence during surgery for many years, the senior author (MGL) has brought this technique into the cadaver lab to help dissect more difficult areas such as the palms of the hands and soles of the feet. The word, tumescence simply means swelling of tissues. When used in the context of surgery or dissection technique, it refers to the active introduction of a tumescent fluid into interstitial spaces in preparation for dissection.

Historically, prior to the development of intravenous catheters, tumescence was the primary means by which fluid resuscitation was carried out in patients who could not take fluids by mouth. The term, clysis, was, and still is, used to describe this sort of tumescence. More recently, this method of hydration has been revisited in cases when intravenous fluids would be difficult, such as in nursing home patients who were unable or unwilling to maintain an IV (Duems Noriega and Arino-Blasco 2014; Hussain and Warshaw 1996). Clysis has also been used in the treatment of burns. Fluid is injected beneath the burn eschar delivering active agents – dilute iodine and a vasopressor – to decrease the risk of blood loss, infection, and sepsis (Allorto-Bishop et al. 2015; Sinha et al. 2003). Tumescence has been used during facial surgery, where the fluid assists in separation of planes, and delivers active agents for anesthesia and vasoconstriction (Jones and Grover 2004). During a mastectomy, tumescence can assist with a less traumatic separation of tissue planes and the delivery of an active agent for vasoconstriction. Improved flap elevation and preservation has been reported with tumescence (Ng et al. 2019).

In the cadaver lab, tumescence delivers an active agent – the wetting solution – into all tissue planes instead of just being sprayed onto the surface. And most importantly, as during mastectomies and facial surgery, it can facilitate the identification of natural tissue planes, transforming what are often desiccated and adherent planes to more hydrated and mobile planes akin to those in a living patient.

Methods
Prior to the beginning of dissections in more challenging areas such as the hand and feet, tumescent fluid was injected into the interstitial tissues of the cadavers using a 30cc syringe and a blunt-tipped cannula (Fig. 1A). Alternately, a similar infusing cannula with a luer lock connection can be used with a 10cc or 20cc syringe. The tumescent fluid consisted solely of the wetting solution used in our anatomy lab: a mixture of 80% water, 18% propylene glycol, 0.4% phenoxyethanol, and 6oz. Sanisol 7® detergent disinfectant (Trinity Fluids) per gallon of solution. The entry site was created with scissors or the tip of a mosquito clamp. The tip of the cannula was inserted into the space immediately beneath the dermis and advanced one to two centimeters (Fig. 1B). It was then further advanced while injecting the tumescent fluid such that there was little to no resistance to the cannula. The cannula was used to gently find the natural tissue plane as the path of least resistance. More tumescent fluid was injected while withdrawing the cannula. This provided additional hydrodissection (Figure 1C).

The plane was opened with blunt-tipped dissecting scissors, such as curved Mayo scissors, and the skin freed up and kept intact for surface orientation and a protective cover (Figure 1D).

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Tumescence in Cadaveric Dissection: A Teaching Perspective

Figure 1. Infusion of tumescent fluid. A. Blunt-tipped cannula with multiple perforations for fluid infusion. B. After creating a small opening with the tip of a mosquito clamp, the cannula is introduced into the space immediately below the dermis. C. The tumescence expands along the natural tissue plane, aiding the preliminary dissection. D. Curved blunt-tipped dissection scissors are used to free up the skin immediately beneath the dermis.

Figure 2. Dissection following tumescent fluid infusion. A. After cutting along each side with scissors, the skin is kept intact and reflected. B. After the structures in the superficial layer are traced and preserved, the next layer is readily accessible. C. The tumescence helps with deeper planes as well, allowing for the rapid identification of structures and relationships. D. The preserved skin provides a reliable barrier to desiccation. E. The intact skin allows for correlation of surface anatomy with underlying structures.

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As the skin was reflected, finer structures that are often adherent to the skin, such as cutaneous nerves, readily dropped down thanks to the increased interstitial fluid (Figure 2A). Blunt spreading with a curved mosquito clamp quickly revealed cutaneous nerve branches (Figure 2B). Deeper structures were separated and cleaned in a similar fashion (Figure 2C) and the preserved skin was used as a natural cover to help prevent desiccation (Figure 2D). Furthermore, replacing the reflected skin also allowed students to readily correlate surface anatomy with underlying structures (Figure 2E).

The same technique was also used in the more challenging palms of the hands. The palmar skin was kept intact, as on the dorsum, and delicate nerves and vessels were likewise dropped down from the skin with scissor dissection (Figure 3). Additional tumescence was infused as needed to maintain a hydrated field similar to that in the living hand.

**Benefits**

From the senior author’s perspective as a hand surgeon, tumescence in the cadaver lab helps transform the challenging post-mortem contraction and adherence of tissue planes in the cadaver to more life-like conditions. This allows for a more pleasant and thorough dissection of finer structures (Figure 4). Very fine structures, such as the nerve extending to a lumbrical, can be quite easily identified and preserved in the moistened environment (Figure 5).
Tumescence was also used in the particularly challenging area of the sole of the foot where separation of layers and identification of deeper structures is carried out with minimal transection of overlying structures (Figure 6).

Discussion
In light of the benefits associated with the use of tumescence, one may wonder why it is seldom used in most anatomy labs. When the senior author began using tumescence in surgery thirty years ago, it was rarely used in that setting as well. As the years passed, and its benefits were recognized, its use became more widespread. Anatomists, much like surgeons, develop and become accustomed to their individual dissection styles and techniques. A new technique, no matter how helpful, brings with it the challenge of change. Tumescence changes the appearance of tissues and makes the field wet and a bit messy.

After successfully dissecting for many years, one may question the need for novelty with its commensurate inconvenience and learning curve. However, if the thought of dissecting an area such as the palm or sole brings on a sense of dread, then the challenge of change may be worth taking. After beginning with palm and sole dissections, the senior author now uses tumescence in all areas of the body wherever a particular donor’s tissues are desiccated or adherent. The increase in interstitial space always facilitates the identification and separation of structures along natural tissue planes.

Conclusion
Tumescence in cadaver dissection is a useful technique of hydrating and expanding the interstitial space, allowing for greater ease of dissection, identification of natural tissue planes, and preservation of finer structures.

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Making a Significant Mid-Career Change as a Female in STEM Academia

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Abstract
A gender gap in science, technology, engineering, and mathematics (STEM) exists. Fewer females enter academia or advance to senior level positions in academia than the number of females who earn advanced degrees. There are many reasons for this, but common themes include disproportionate responsibilities for childcare and imposter syndrome. For some females, this may mean a reluctance to undertake a mid-career change. In this article, I relate my experience with a mid-career change and how I adapted to a new academic environment with new responsibilities. In doing so, I realized that my current approach is not much different than my previous approach and I was able to adjust to teaching professional students and mentoring graduate students in research after having spent 20 years at an undergraduate teaching institution.

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Key words: undergraduate, graduate, dental, gender, women, career change

Introduction
After a 20-year career of teaching human anatomy and physiology at a community college, I accepted a tenure-track position with a research component at a school of dental medicine. Many females in the STEM field experience barriers throughout their career. Such barriers include, receiving fewer grant awards as well as being encouraged to accept higher teaching and service loads than comparable male faculty. In addition, many females experience imposter syndrome. Imposter syndrome (or, imposter phenomenon) originates from a 1978 study (Clance and Imes 1978) of extremely successful females who, despite their accomplishments, still felt insecure and not deserving of their successes. Overcoming imposter syndrome, and other barriers to females in STEM academia, is achieved through explicit attempts to develop a network of support and being willing to accept certain vulnerabilities that accompany new career prospects. In this article, I will explore the gender gap in STEM academia and how I am navigating a mid-career transition. I will relate what others say about mid-career transitions and share my own experience and provide what I hope is useful insight to other females considering similar career transitions.

STEM Gender Gap
In STEM academia, there is a gender gap. Females hold only 22% of full professorships at doctoral universities with R1 designations—those that meet certain criteria in research activity and expenditures (Lerchenmueller and Sorenson 2018; Carnegie Classifications of Institutions of Higher Education). Among medical schools, only 18% of department chairs and 17% of deans are held by females, yet females represent 50% of health care professionals (Lewiss et al. 2020). Furthermore, analysis of data published by 130 U.S. universities demonstrated that only about 22% of them had a female as president, while approximately 39% of deans and provosts at these universities were comprised of females (Silbert et al. 2022).

Possible Causes of the STEM Gender Gap
A 2019 report from the Council for Graduate Schools indicated that acquisition of higher education degrees is not a limiting step for females entering academia—60.1% of master’s degrees and 53.1% of PhD degrees are awarded to females in the U.S (Council of Graduate Schools 2020). Rather, the gender gap appears to be due to fewer females with advanced degrees entering academia entirely or advancing to senior level positions in academia.

Fewer females entering academia appears to be due to either self-selection or external forces. In a 2011 study (Goulden et al. 2011), 44% of females reported that child-related concerns prevented them from applying for tenure-track faculty positions with a research component. Yet, when married females with young children do apply for tenure-track faculty positions, they are 35% less likely than males to be hired (Ysseldyk et al. 2019). Thus, there are also external forces that prevent females from entering academia. As further illustration of this, in a 2012 study, a greater number of male-identified job applications were ranked higher than female-identified applications when compared to the same application pool that was gender-blind (Moss-Racusin et al. 2012).
et al. 2012). Among the gender-blinded applications, it was revealed that a greater number of female applications were ranked higher than male applications.

Some females who have entered academia have not advanced to senior level positions, despite decades of experience. This contrast between the number of higher education degrees awarded to females and the number of academic positions (both entry level and senior level) held by females is referred to as the “leaky pipeline.” Somewhere along the line, females leave the path toward full professorship in academia. The underlying causes of this gender gap are numerous and complex, but the common factors are childbirth and childcare. Females disproportionately engage in childcare and domestic responsibilities (Cardel et al. 2020). For example, a pre-requisite for tenure in many academic institutions is receipt of federal grants, yet females submit fewer than 30% of all NIH grants and make up only about 30% of grant awardees (Hechtman et al. 2018). Publication is also a pre-requisite for advancement to senior levels in most academic institutions.

Morgan et al. (2021) reported that female computer science faculty, on average, published 17.6 fewer papers than male faculty for up to a decade after having a child. However, they report that the effect of becoming a parent on total productivity over a person’s career is relatively small.

Although childbirth and childcare may be a conscious choice by females in academia, other causes of the gender gap are more subtle and may partially contribute to imposter syndrome. For example, much emphasis is often placed on recruitment of novice female faculty into academic medicine. These faculty are reported to receive significant mentorship and career-development focus, often by older male faculty (Carnes and Bigby 2007). However, as these female faculty advanced toward mid-career having made significant scientific contributions, they were reported to be marginalized by the same previously supportive male faculty. Kaatz and Carnes (2014) proposed that this could be due to the females being a perceived threat to the advancement of the male faculty.

The past decade has also seen an overall decline in academia culture (Gewin 2022), partially due to less pay despite an increased workload. This is particularly true in that there are a greater number of administrative tasks such as more required trainings and increases in required institutional documentation that accompany scientific laboratory research. Fewer than 60% of faculty reported satisfaction with their job partly because they felt that they were receiving a constant stream of ‘constructive’ criticism (Woolston 2021). For females experiencing imposter syndrome, this continuous constructive criticism can create a perception that they are not deserving of their position and is particularly damaging. In a 2021 article providing academic career advice to graduate students and junior faculty, Jennifer Snodgrass, a tenured, full professor at Appalachian State University wrote, “Imposter syndrome never really goes away” (Snodgrass 2021).

Academia is a setting in which faculty are continuously held to a high standard in both teaching and research. In particular, researchers are under substantial pressure to be self-motivated in order to acquire funding for and to advocate for their work. This constant push to improve and expand is one reason why the academe is a major source of new ideas, new discoveries, and inspiration for the world. However, by the same token, this environment can initiate and exacerbate imposter syndrome in females. To help reduce the gender gap in STEM academia, academic institutions need to do more for females in STEM fields, including fostering re-entry into research positions by mid-career or returning females.

### How to Navigate a Mid-Career Transition as a Female in STEM Academia

Making a significant career transition as a female over 40 years old, whether it is re-entry into a research position, or a total career re-launch after a hiatus, requires a network of support. Those undergoing a mid-career transition face a paradox of having previous job experience but are entering a new environment. Higher education institutions often approach entering, experienced faculty the same as they do novice faculty members (Cherrstrom and Alfred 2020). Mid-career transitioners reported their age as a detriment—they felt that on day one they were already behind in goal achievement when compared to their same age peers with tenure. In a study that followed female midlife career changers ages 35-60, the following recommendations emerged: 1) regardless of prior success, females need support and encouragement, 2) it is critical to take specific actions to create a supportive network at a new institution, and 3) it is extremely helpful to draw on prior experiences and apply them to a new position (Cherrstrom and Alfred 2020). In the next segment, I will highlight how I have implemented these three recommendations.

**Regardless of prior success, females need support and encouragement**

My husband and I are both PhD biologists and, two decades ago, were on the job market for faculty positions at liberal arts colleges. At that time, I was 8 months pregnant with our first child. Initially, I found work as an adjunct faculty member at three separate college campuses and spent more money on gas and childcare than I earned. After the first year, I accepted a position at a local community college and over the next 20 years, earned tenure and eventually full professor status. Even though I loved my job, I decided to apply for a physiology tenure-track faculty position at a nearby dental school. I found the prospect of teaching more advanced physiology and re-launching a research program to be an appealing challenge.

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I began my new position in June 2020 at the height of the COVID-19 pandemic. My first year of teaching at the dental school was all virtual, and through student feedback, learned that most students found my teaching ineffectual, which significantly reduced my self-confidence. To help counter this, I sought input from my female department chair, a female colleague with 30 years of experience at the dental school, and a female colleague with 5 years of experience at the dental school—all three of whom have been encouraging, have offered helpful advice that helped boost my self-confidence, and gave me specific guideposts for teaching dental students. For example, they suggested I specifically relate physiological concepts to dentistry. To do this, I created vignettes called, “A Dental Moment” to highlight application of certain concepts to dentistry during didactic lectures. These vignettes have received positive feedback from students.

It is critical to take specific actions to create a supportive network

A 2014 article titled, “Taking a break from the lab: Can it really be done?” (Skok 2014) provides some pointers for re-entry into the research lab such as finding a mentor to support you. I was able to quickly identify a mentor when I arrived at the dental school. Her career path was very similar to mine, and she had established a research program at the dental school after a career hiatus. Her guidance and insight have been essential to me in these first few years. We have collaborated on several projects, submitted a federal grant proposal together, shared undergraduate mentees in our labs, and have become good friends. With her help, the help of my husband, and the help of my former PhD advisor, I have promising research projects underway in my new lab.

It is helpful to draw on prior experiences, and apply them to a new position

I learned a lot about myself and my teaching philosophy during my first two years at the dental school. I have learned that, for me, ‘teaching is teaching is teaching.’ In my previous position, I centered my physiology teaching around the Core Concepts of Physiology framework (Michael and McFarland 2011; 2020). However, I had a misconception about what teaching first-year dental students would entail. I mistakenly and incorrectly thought that these students would have a solid grasp of the fundamentals of biological sciences, and to be clear, many do. But some students arrive as first-year dental students from diverse undergraduate paths. Many first-year dental students that I have taught have approached the biomedical didactic courses at my school with some reluctance because they view the information within as not relevant to them as future clinicians. However, the fundamental knowledge they acquire is important for them to have a working understanding of human health and disease. But beyond this, critical thinking and problem-solving is an important competency for dental students according to the American Dental Education Association (ADEA). As Chirillo et al. (2021) point out, incorporation of the Core Concepts of Physiology teaches “pattern recognition”, which allows for effective clinical thinking. As further evidence of the need for ensuring a strong set of fundamentals for health professional students, Bordes et al. (2021) reported that first-year medical students held misconceptions regarding cardiovascular physiology and Badenhorst et al. (2021) demonstrated that retention of certain misconceptions by medical students continues throughout the entire medical curriculum. By utilizing the physiology core concepts framework, students learn over-arching concepts, then layer in particular details. To assist student with this layering in, I assign critical thinking questions as homework, present case studies during didactic lectures, and administer exams that contain application-based short answer written questions—all techniques I used with community college students.

After two years, I understand the first-year dental students at my institution much better. I have been able to apply my prior experiences with community college students to my new situation. Students excel when there is a framework for learning such as the Core Concepts of Physiology. Such a framework allows students to fully incorporate information into their knowledge base to be able to problem solve. Using the Core Concepts of Physiology has been substantial in my progression as a professor; by having this framework, I feel more confident because it provides a built-in structure on which to build my lectures. It feels like a safety net so my self-view as an imposter has begun to wane a little.

To Shrink the Gender Gap, Systemic Change is Needed

When a former colleague informed her provost that she was expecting a second child, he conveyed his disappointment to her that her productivity would decline and she felt undermined by him. Indeed, Kaatz and Carnes (2014) report that “top down” solutions stemming from upper administration help slow the leaky pipeline much more effectively than those that place the onus onto the female faculty members. For example, implementation of gender-bias training, mentorship, sponsorship, and leadership training and providing internal grants to faculty with family care responsibilities have all been reported to enhance female faculty retention and advancement (Lewiss et al. 2020).

In Australia, many universities have implemented programs, called Phased Return, that allow individuals returning from long-term primary caregiver duties to restart at an 80% effort level for 40 weeks while continuing to receive 100% of their salary (Laver et al. 2018). In addition, many Australian universities have flexible work arrangements, child-friendly office space, and breast-feeding rooms. These universities continued on next page
also offer Career Interruption grants up to $10,000 that a faculty member may receive more than once and can be used for activities that support the return to work such as course buy-outs, or conference attendance. There are re-entry grants in the U.S. that are by funded the NIH; however, to be eligible for these grants, the career interruption must be 8 years or less. Universities in the U.S. should consider implementing, or expanding, a broad diversity of programs that support female faculty facing family care obligations.

Conclusions
Females returning to STEM academia due to a career transition, such as mine, or a return to academia after a hiatus need extra support and mentoring. This type of support gave my self-confidence a needed lift. Female faculty should trust themselves to develop and nurture the qualities needed to earn a master’s or doctoral degree: being courageous, being tenacious, and being self-motivated. I have found that I have been able to transition from teaching undergraduates to being able to challenge dental students. First year health professional students, such as dental, medical, or pharmacy students still need reinforcement of core and all foundational concepts. I have found I need to confirm what the first-year dental students have learned earlier, reinforce this, and then guide them through application of the concepts to their specific content area. I have also been able to re-launch a research program that, while still in its infancy, has the potential to be strong. I have been significantly guided by my research mentor at my new institution; without her input, I would have been incredibly lost and behind. In the end, many faculty members, including me, encourage students during challenging times to persist and not waver from their goal. Female faculty should apply that sentiment to themselves as well as their students.

About the Author
Cinnamon L. VanPutte earned a PhD at Texas A&M University in 1998. In 2000, she joined the faculty at Southwestern Illinois College where she remained until 2020. In June 2020, she joined the faculty at Southern Illinois School of Dental Medicine where she teaches physiology to first year dental students. Her research lab focuses on the effects of microbiome depletion on thyroid function and their relationship to periodontal disease. She is one of the authors of Seeley's Anatomy & Physiology and Seeley's Essentials of Anatomy & Physiology (McGraw-Hill), which emphasizes development of critical thinking skills.

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The Hormone Project: Application of Art to Engage Critical Thinking for Undergraduate Medical Education

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Abstract

Active learning is a technique used to help transfer passive knowledge into true learning of material, which can be very beneficial when learning challenging topics. The endocrine system is a complex series of topics that can be challenging to tackle in the short amount of time allotted to it in the medical school curriculum or an undergraduate anatomy and physiology course. Pedagogical strategies that use art as a tool have been shown to motivate and induce students to self-learn such complex physiology topics. The hormone project was designed to help students manage the vast amount of information and acquire knowledge in a meaningful and creative way. Students were asked to create a visual project to depict an endocrine disorder that incorporated art into their learning of the endocrine system. Based on post-session survey results, students found the activity to be beneficial to their learning and they enjoyed engaging in the activity. Providing students with opportunities to engage with material in a creative, artistic manner can be both engaging and enjoyable. This activity provided students with a chance to develop their own memory hooks to facilitate easier recall of the complex topics in the endocrine system. A pilot study of this activity shows great promise to be a staple in curricula that embrace active learning.

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Key words: active learning, physiology, medical education, art in medicine

Introduction

One of the great challenges in teaching physiology is finding a way to make the endocrine system interesting and straightforward to understand, while engaging students in the learning process. This challenge is one that exists at nearly all levels of education for learners, from high school students first learning about the endocrine system to medical students who are applying more advanced facets of the endocrine system to include disease processes and treatments. Through observations and direct experience with students, as well as curriculum evaluation and review, we have found that students significantly reduce the time they spend undertaking activities such as textbook reading and attending (or watching a recording of) passive lectures. The students of today prefer resources that approach the delivery of material and in developing their critical thinking skills (Housen 2002; Naghshineh et al. 2008; Perry et al. 2011). Studies such as the PhysioArt project directed students to incorporate physiological concepts into already established works of art (Flôr et al. 2020). From this work, students confirmed that integrating art into the study of physiology with PhysioArt was an effective method to learn and that their project increased their interest in physiology (Flôr et al. 2020). This concept of applying art to physiology (as well as other sciences) was the underlying goal of the pilot project for the “Hormone Project” described here.

This perspective represents the first of its kind to use a team-based artistic approach to teach the endocrine system to medical students. It provides a type of mind-mapping to traditional didactics and found them to be a valuable teaching tool (El-Sayed and El-Sayed 2013).

Other innovative approaches to teaching physiology include integration of art and creativity into the teaching practice. It has been shown that integrating art into topics such as biology has aided in improving student enjoyment of the material and in developing their critical thinking skills (Housen 2002; Naghshineh et al. 2008; Perry et al. 2011). Studies such as the PhysioArt project directed students to incorporate physiological concepts into already established works of art (Flôr et al. 2020). From this work, students confirmed that integrating art into the study of physiology with PhysioArt was an effective method to learn and that their project increased their interest in physiology (Flôr et al. 2020). This concept of applying art to physiology (as well as other sciences) was the underlying goal of the pilot project for the “Hormone Project” described here.

This perspective represents the first of its kind to use a team-based artistic approach to teach the endocrine system to medical students. It provides a type of mind-mapping
procedure where students need to brainstorm, research, compare, contrast, consolidate, and organize a variety of disciplines and clinical considerations, related to a pathology that is significant to the students as a central theme. There is growing evidence of the benefits of mind mapping for learning and retention (Adodo 2013; Erdem 2017; Heideman et al. 2017; Kalyanasundaram et al. 2017). The Hormone Project activity first relies on teamwork to determine the most appropriate content. It then allows for the learners’ creativity to take over in designing an image that is helpful to them instead of relying on commercially available resources that may be considered too difficult or contain obscure references, which in themselves would need to be studied so that they are understandable to the student. This work compliments the array of team-based learning, problem based learning, and interactive case studies currently available in the literature for the endocrine system.

Methods

Project Implementation and Facilitation:

The Hormone Project was initially designed for first-year medical students, in the early phases of study with the endocrine system, as part of an organ systems-based curriculum that assists students with integrating the various basic and clinical science concepts. The Hormone Project activity was implemented during the Gastrointestinal, Human Nutrition, Endocrine, and Reproductive (GIHNER) organ systems course which is the fourth official course in the sequence of the basic science curriculum. GIHNER is preceded by the Professional Immersion, Fundamentals, and Hematology courses and it is strategically placed to build on knowledge acquired from these prior blocks. The Hormone Project was placed at the beginning of the second week of the endocrine system portion of the GIHNER course. Students had approximately half of the endocrine system content in physiology, pathology, pharmacology, biochemistry, and anatomy prior to this activity. This placement was important to allow for the students to be familiar with the concepts and to support integration of the material.

During the in-class portion of the activity, faculty facilitators helped to guide the students to stay on topic and to facilitate small group dynamics. The facilitators were not required to have prior knowledge of the curricular content in order to facilitate the activity and were provided with a facilitator’s guide (Table 1) for the activity. A facilitator meeting was also held one week prior to implementation to review facilitator roles and session logistics.
Objectives:
1. Identify hormones of the endocrine system and their regulation.
2. Identify the effects of hyper- and hypo-secretion of hormones.
3. Associate clinical findings and pathophysiology for endocrine abnormalities.
4. Determine appropriate standards of diagnosis and treatment for endocrine abnormalities.
5. Create a novel study aid for endocrine diseases.

Directions:
This project is a dive into the endocrine system that consists of two parts.

Part 1:
Student groups will complete a comprehensive table covering selected hormones of the endocrine system. Each group will have a unique table to complete. At the end of the first hour, each group will submit 1 table for their group submission. Please ensure that the group number and all group members names are on the document.

Topics for part 2 will be given by the facilitator once the table from part 1 is submitted.

Released as part 1 is turned in: Comprehensive hormone table and disorder for each group.

Part 2:
Using the hormone table (see Part 1), students will use their collective creative powers to create a “Sketch-E” (short for Sketch-Endocrine) study aid for the endocrine disease/disorder the group has been assigned. The project should be an original depiction of the topic and include:

1. clinical presentation and epidemiology
2. lab tests
3. hormones involved
4. feedback involved (in (4a) a healthy individual and (4b) where the disease can affect)
5. common causes
6. treatments
7. pathophysiology behind the disease and widespread effects.

Everyone is expected to participate in the activity in some way. The “Sketch-E” final product must contain a key for the image indicating how the different components are addressed.

Facilitators, please help students to ensure that the work is original and not just a copy or close resemblance of an existing resource/study aid.

Projects may be drawn on the whiteboard for a photograph or some other electronic product (PowerPoint, Word, Notability, etc.). It is highly recommended that they use something that they can revisit to edit, as they may not complete this in the 1 hour they have in session to complete and may need to return to it later.

Each group is responsible for generating one final product.

At the end of the day, students must submit either a screen shot or picture of their progress. This will be emailed to the facilitator and course directors. This will likely be a draft after one hour, and the students will need to complete their image by Friday. If they complete this in class, awesome!

At the completion of the projects, they will be shared with the other groups.

For the Friday submission, students must take a picture of the final product and submit the picture and key to the assignment by the deadline.

Topics will include:
• Addison’s Disease
• Growth Hormone Deficiency in Children
• Prolactinoma
• Type I Diabetes Mellitus

• Hyperaldosteronism
• Syndrome of inappropriate antidiuretic hormone secretion (SIADH)
• Hyperparathyroidism

Table 1: Facilitator Guide: Group Project: The Hormone Project
Students completed the activity in their previously established problem-based learning groups of 7-8 students per group. The 100-minute activity was divided into two parts. At the start of the activity, students were given part one of their directions (corresponds to Table 1, Part 1) and then completed a Microsoft Excel workbook, which contained categories for completion for 5-6 unique but related hormones. Each group specifically completed the hormones’ regulation, effects of hyper/hypo secretion, pathophysiology of the hyper/hypo secretions, treatments, and any related genetic components. At the conclusion of the first 50 minutes, one group member turned in the completed table for the group and a 10-minute break was taken.

For part two of the activity, each group was given the second set of the directions (corresponding to Table 1, Part 2) and was assigned a specific endocrine disease/disorder. For each disorder, students were asked to design a picture representation of the clinical presentation and epidemiology, lab tests, hormones and feedback involved (in a healthy individual and where the disease causes changes), common causes and treatments, and pathophysiology behind the disease and widespread effects. Students spent the remainder of the in-class activity time working on a draft of the image which was submitted to the block directors at the end of the 100 minutes (to encourage work to be completed in the session). Each group was then given 3 additional days to finalize the project, and one member from each group was asked to submit the completed image and the key to their learning management system.

Assessment

The table including hormones and information from part one was graded for accuracy of medical knowledge and completeness. For part two, a predesigned rubric (Table 2) for the project was used. Students received a combined grade for both parts, which accounted for 4% of their total grade for the GHNTER course.

<table>
<thead>
<tr>
<th>Table 2: Group Project: The Hormone Project Rubric for Part 2</th>
<th>3 points</th>
<th>2 points</th>
<th>1 point</th>
<th>0 points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Originality, creativity, cohesiveness of project</strong></td>
<td>Project is not a duplication of existing work, demonstrates creativity, and is a thorough representation of the assigned disease</td>
<td>One aspect is missing</td>
<td>2 aspects are missing</td>
<td>Not original or creative and not a relevant representation of the disease</td>
</tr>
<tr>
<td><strong>Key for the image</strong></td>
<td>All aspects of the project are explained/identified in the key</td>
<td>Missing 1 aspect</td>
<td>Missing 2 aspects</td>
<td>Key not present or complete (missing more than 2 aspects) OR key does not explain the image</td>
</tr>
<tr>
<td><strong>Clinical presentation and epidemiology</strong></td>
<td>Accurate, thorough, and contains no errors or omissions</td>
<td>One aspect is missing or inaccurate</td>
<td>2 aspects are missing or inaccurate</td>
<td>More than 2 aspects are missing or inaccurate</td>
</tr>
<tr>
<td><strong>Lab tests</strong></td>
<td>Diagnostic tests present and accurate</td>
<td>Missing 1 important diagnostic test</td>
<td>Missing 2 important diagnostic tests</td>
<td>Missing more than 2 tests or contains errors</td>
</tr>
<tr>
<td><strong>Treatments</strong></td>
<td>Pharmacological and nonpharmacological (if applicable) treatments present and explained (MOA).</td>
<td>Missing 1 common treatment or explanation.</td>
<td>Missing 2 common treatments or explanations</td>
<td>Missing more than 2 treatments or explanations OR contains errors</td>
</tr>
<tr>
<td><strong>Hormones and Feedback (normal)</strong></td>
<td>Key hormones and feedback present</td>
<td>Missing an aspect of feedback</td>
<td>Missing more than one aspect of feedback or 1 key hormone</td>
<td>Missing more than 1 key aspect of feedback, more than 1 hormone, or contains errors</td>
</tr>
<tr>
<td><strong>Hormones and Feedback (abnormal)</strong></td>
<td>Diseased state differences in hormone production or feedback indicated and accurate</td>
<td>Missing 1 aspect of diseased state/feedback changes</td>
<td>Missing 2 aspects of diseased state/feedback changes</td>
<td>Missing this section or contains more than 2 errors</td>
</tr>
<tr>
<td><strong>Causes/Pathophysiology</strong></td>
<td>Present with no errors or omissions</td>
<td>Missing 1 aspect</td>
<td>Missing 2 aspects</td>
<td>Missing more than 2 aspects or contains errors</td>
</tr>
</tbody>
</table>

continued on next page
In addition to the products turned in by the students, the facilitators also completed a rubric to assess professionalism and participation during the 100-minute activity. Topics from this rubric related to each individual student’s level of participation, ability to work in a team, and how well they stayed on track during the in-class portion.

**Project Evaluation:**

To identify how the students perceived the activity, an anonymous survey was given using the Microsoft Forms platform. The questions were adapted from Wiggins et al.’s ASPECT: A Survey to Assess Student Perspective of Engagement in an Active-Learning Classroom survey, with modifications to be specific to the Hormone Project and use of facilitators (Wiggins et al. 2017). The full list of questions is provided as in Table 3 with the results. The students completed the survey during their Reflection, Integration, and Assessment Week, after completing their final exam, which was approximately 4 weeks after completing the activity.

This study was determined as exempt by the Nova Southeastern University IRB (#2022-138)

**Results**

39 of the 52 potential students (75%) completed the voluntary survey. Students rated the Hormone Project activity as very high on the value of the group work (survey items 1-9), on their personal effort (survey items 10-12), on the instructor/facilitator contributions relating to active learning (survey items 13-16), and the overall project itself (survey items 17-19) as can be seen in Table 3. The Cronbach’s alpha for the survey was 0.92, indicating high reliability for the survey responses.

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Mean Value +/- Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Explaining the material to my group improved my understanding of it.</td>
<td>5.29 +/- 0.80</td>
</tr>
<tr>
<td>2. Having the material explained to me by my group members improved my understanding of the material.</td>
<td>5.26 +/- 0.79</td>
</tr>
<tr>
<td>3. Group discussion during the Hormone Project contributed to my understanding of the course material.</td>
<td>5.29 +/- 0.80</td>
</tr>
<tr>
<td>4. I had fun during the Hormone Project group activity.</td>
<td>5.34 +/- 0.71</td>
</tr>
<tr>
<td>5. Overall, the other members of my group made valuable contributions during the Hormone Project activity.</td>
<td>5.44 +/- 0.64</td>
</tr>
<tr>
<td>6. I would prefer to take a class that includes this hormone Project activity over one that does not include this activity.</td>
<td>4.74 +/- 1.37</td>
</tr>
<tr>
<td>7. I am confident in my understanding of the material presented during the Hormone Project activity.</td>
<td>5.21 +/- 0.78</td>
</tr>
<tr>
<td>8. The Hormone Project activity increased my understanding of the course material.</td>
<td>5.18 +/- 0.93</td>
</tr>
<tr>
<td>9. The Hormone Project activity stimulated my interest in the course material.</td>
<td>5.05 +/- 1.06</td>
</tr>
<tr>
<td>10. I made a valuable contribution to my group during the Hormone Project.</td>
<td>5.50 +/- 0.60</td>
</tr>
<tr>
<td>11. I was focused during the Hormone Project activity.</td>
<td>5.47 +/- 0.64</td>
</tr>
<tr>
<td>12. I worked hard during the Hormone Project activity.</td>
<td>5.18 +/- 0.69</td>
</tr>
<tr>
<td>13. The facilitator’s and/or block directors’ enthusiasm made me more interested in the Hormone Project activity.</td>
<td>5.18 +/- 0.90</td>
</tr>
<tr>
<td>14. The facilitator and/or block directors put a good deal of effort into my learning for the Hormone Project.</td>
<td>5.08 +/- 1.05</td>
</tr>
<tr>
<td>15. The facilitator seemed prepared for the Hormone Project activity.</td>
<td>5.11 +/- 0.89</td>
</tr>
<tr>
<td>16. The block directors or facilitators were available to answer questions during the group activity.</td>
<td>5.32 +/- 0.84</td>
</tr>
<tr>
<td>17. The visual product made for the Hormone Project was beneficial to my learning.</td>
<td>5.32 +/- 0.90</td>
</tr>
<tr>
<td>18. The table for part one of the Hormone Project was beneficial to my learning.</td>
<td>4.84 +/- 1.20</td>
</tr>
<tr>
<td>19. The timing of the Hormone Project was appropriate in the course (in week 2 of Endocrine focus).</td>
<td>5.15 +/- 1.10</td>
</tr>
</tbody>
</table>

Cronbach’s alpha = 0.92

*Table 3. Survey results related to Active Learning for the Hormone Project.*
To highlight a subset of data, the majority of the students found that the Hormone Project increased their understanding of the course material (43.6% strongly agree, 42.0% somewhat agreed, and 10.3% agreed) and was beneficial to their learning (53.8% strongly agreed, 30.8% somewhat agreed, and 12.8% agreed) as can be seen in Figures 1a and 1b.

When asked what aspect they enjoyed most about the Hormone Project in the free response portion of the survey, the key themes in the comments were an overwhelming statement that the art project and use of creativity was enjoyed (61% of the total responses), collaboration and teamwork (19% of the total responses), along with the interactivity (7%) and just overall it was a good project/use of time (13%) as can be seen in Figure 2.

**Figure 1.** Highlighted student poll results. Figure 1A shows that students had some level of agreement that the Hormone Project increased their understanding of the course material (95.9% were at “agree” or higher). Figure 1B shows that students had some level of agreement that the Hormone Project was beneficial to their learning (97.4% were at “agree” or higher).

**Figure 2.** Student narrative results. Narrative statements given by the students on free response to the question “Please identify one aspect you enjoyed about the Hormone Project.” The top two aspects were creativity (61% of the total responses) and collaboration/teamwork (19% of the total responses).
To provide a representation of the type of product which can be expected, Figure 3 is a student-made product with the full key which was submitted for the Hormone Project (provided anonymously with written consent from the group). The figure represents Addison’s Disease as depicted by the students of that group.

**Figure 3.** Representation of final student-created product of the Hormone Project. Figure 3 shows a representation of a student prepared submission with accompanying key for their artwork: DESTRUCTION AT PAI AIRPORT: The one where Addison eats too many tacos. KEY: 1. Clinical Presentation (and Widespread Effects) Rust Spot on the grounded airplane: Hyperpigmentation (mainly of the skin and mucous membranes) Oil Leaking from the grounded airplane: GI Upset Addison (also known as Lola) laying on the ground: Orthostatic Hypertension and Extreme Fatigue 2. Epidemiology Addison laying on the ground: Occurs more commonly in women in their 30’s-50s 3. Labs Bananas on the Runway: Hyperkalemia Salt Shaker on the Runway: Hyponatremia Trippy Smile on the Taco Truck: Metabolic Acidosis Rising Sun: Low Morning Cortisol Palm Tree: Elevated POMC Sunscreen: Elevated MSH (resulting in the hyperpigmentation) AC’s Taco Hut: Elevated ACTH Candy Jar Tipped Over Off Truck: Hypoglycemia “Flight at 11 to DC is Delayed”: Low 11-Deoxycortisol 4. Hormones Involved Three Triangle Signs with Arrow Pointing Down: All three major groups of steroid hormones (mineralocorticoids, glucocorticoids, and androgens) are diminished 5. Feedback Involved Healthy Individuals: Plane in the sky: cortisol (the glue) is present in these individuals that then negatively feedbacks on CRH and ACTH Those with Addison’s Disease: Plane on the runway: cortisol (the glue) is not present and cannot negatively feedback on CRH and ACTH and take off 6. Common Causes Suitcase with a tag that reads “TB” and a cactus Stamp: Most common cause of Addison’s in developing countries is Tuberculosis Suitcase with an immunoglobulin tag: Most common cause of Addison’s in Western countries is autoimmune destruction 7. Treatments Glue bottle next to the grounded plane: Glu(e)corticoid/Mineralocorticoid replacement 8. Pathophysiology: Plane on the ground with visible mechanical issues: Destruction of the adrenal gland — decrease in cortisol and aldosterone — plane not able to take off PAI Airport: Primary Adrenal Insufficiency 9. Genetics HLA B8, HLA D3-4 Sign: links between Addison’s disease and HLA-B8, HLA-DR3, and HLA-DR4.
Discussion
The Hormone Project is a unique learning activity that combines art with medicine, creating an active learning activity which was engaging, enjoyable, and educational for the students. This unique team-based artistic approach was developed to respond to the unfavorable outcome from the previous iteration of the Hormone Project that ran in the previous year. In the preceding iteration, students were required to develop a 10-minute presentation on the disorder that covered the same aspects that are in the current iteration. After one trial run with the presentation style, it was quickly noted that the time allotted for a presentation where 7-8 persons had to speak was inadequate. Students had also noted in course evaluations that they did not enjoy the activity or find it useful. This reimagining of the Hormone Project served to fit in the allotted time and has provided the students with opportunities to participate in their groups in creative ways.

The Hormone Project could be adapted to use for other topics, including cancers, tumors, the reproductive system, or liver diseases as students indicated in their survey responses. Additionally, the project could be scaled down to be just one specific disease or disorder as an in-class activity for active learning during lectures. Using this style, it could be applied to almost any disease/disorder or physiological process. Additionally, though the project as described here was placed to allow the students to have some prior knowledge of the topics, it could be placed elsewhere in the curriculum, provided the students have the appropriate resources to find the information needed for the activity. It could easily be an introductory activity to a topic or a summary to incorporate prior learning.

One limitation of the Hormone Project is that each group prepared and deeply learned only one endocrine disease/disorder. This was a piece of feedback noted by the students on the annual course evaluation. As a means to help to share their products and learning tools with the class, there are plans in the next iteration to share the finished products with the entire class. While each group is still deeply learning one disease/disorder, there would be opportunities to use the learning tools for the other diseases/disorders.

A limitation to the pilot study itself was that only 75% of the students completed the survey, however reassurance came from the high reliability score. One way to address the number of survey responses in the future iterations would be to implement the survey online, immediately after they turn in their projects.

In the next implementation of the Hormone Project, feedback from this most recent iteration will be implemented. With the survey prompt asking students to identify one aspect that needs improvement in the Hormone Project, there were two points that stood out: The students wanted more time to complete the activity in class and they did not enjoy the table for part one. The next cohort of students will be given the part one table (indicated by Table 1, Part 1 above) as pre-work and they will then have a full 100 minutes to dedicate to the art project.

About the Authors
Charity O’Malley is an Associate Professor of Medical Education and Physiology at Boonshoft School of Medicine at Wright State University. Her research goals aim to improve the learning experience for students by helping them learn to study and interact with the material in meaningful ways and for faculty by helping guide them on implementing active learning into their classrooms and is a co-principle investigator for an NSF grant related to this work. She also is actively involved in promoting diversity through her funded research projects centered around enhancing training for medical students related to the LGBTQ population.

Arkene Levy is Director of Diversity Equity and Inclusion (DEI) and Associate Professor of Medical Education at Nova Southeastern University Dr. Kiran C. Patel College of Allopathic Medicine (NSU MD). She has over fifteen years of experience in medical education and a wealth of experience with active learning exercises for multiple teaching modalities including synchronous and asynchronous online learning and face-to-face classroom activities such as problem-based and team-based learning. Dr. Levy has applied her teaching approaches to develop and implement a transformative DEI Curriculum at NSU MD and to deliver sessions related to the basic sciences for a variety of educational programs in the health professions including dentistry, optometry, and pharmacy.

Daniel P. Griffin is the Assistant Dean for Pre-Clerkship Curriculum and an Associate Professor of Medical Education at Nova Southeastern University Dr. Kiran C. Patel College of Allopathic Medicine. He has extensive experience in active learning such as problem-based learning and team-based learning. He has been fortunate to have had opportunities to take educational programs at two new medical schools to full implementation. He also has a history of and is actively involved in promoting diversity, equity, and inclusion in medical school training and processes; and executing projects designed to innovate curriculum delivery methods.
Literature Cited


An Introductory Framework of Problem-Based Learning (PBL) and Perspectives on Enhancing Facilitation Approaches

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Abstract

Problem-based learning (PBL) is a type of active learning modality involving a student-centered approach that encompasses small group settings in order to promote learning via critical thinking and discussion as opposed to via direct presentation of facts and concepts. Through PBL, students engage actively in their learning. Facilitated PBL sessions put an emphasis on active learning by students as they explore their knowledge and understanding of medically related concepts as well as their own attitudes and values. This paper provides an introduction to the PBL modality and tips for developing a facilitation approach. Also included are examples of formative and summative feedback and implementation strategies that can be used by PBL facilitators. An example of a training exercise for PBL facilitation feedback is also presented.

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Key words: problem-based learning, facilitated learning, active learning, feedback

Introduction

Promotion of active learning can involve a broad range of teaching strategies which engage students as active participants in their learning. Active learning has been shown to improve student outcomes and lead to improved critical thinking skills, increased retention and transfer of new information, increased motivation, improved interpersonal skills, and decreased course failure (Kuh et al. 2017; Prince 2004). Active learning teaching approaches range from short, simple activities, such as problem solving and paired discussions, to longer, involved activities or pedagogical frameworks like case studies, problem-based learning (PBL), flipped classrooms, and structured team-based learning (Lord et al. 2012). A student-centered approach typically involves students working together during class but may also involve individual work and/or reflection outside the classroom. The focus of this perspective article is to highlight key steps in the PBL process while providing insights into the successful development of a student-centered facilitation approach.

PBL emerged as a means to reform higher education during the late 1960s as a result of the work of Harold Barrows, a medical educator at McMaster University who studied the reasoning skills of medical students and expert practitioners (Rideout 2001; Savin-Baden 2000; Schmidt 2012; Tanner 1999). PBL became the keystone of the School of Medicine at McMaster University in 1969 (Johnson and Finucane 2000). PBL was heavily influenced by the work of John Dewey whose ideas were based in the philosophy that learners engaged more in the learning process if the learning activity involved was meaningful and of interest to them (Schmidt 2012). It was observed that traditional approaches of teaching did not foster a favorable disposition towards lifelong learning in students, a necessity for healthcare practitioners in today’s society (Alexander et al. 2002; Azer 2001; Rideout 2001; Tanner, 1999). Since that time, there has been incorporation of PBL into the curricula of medical schools throughout the world (Alexander et al. 2005; Baker 2000; Tanner 1999).

PBL Facilitation Approaches

To familiarize educators with the framework of PBL modality and different facilitation approaches that can be practiced for an effective PBL session, the following key aspects of PBL modality and facilitation approaches are imperative:

1) The PBL Modality:

PBL starts with a problem (case) that drives the learning process and is active, collaborative, integrated, and oriented to the way adults learn (Jones 2006). A typical PBL group consists of 6-8 students predetermined by the instructor. These predetermined groups will consist of varying ranges of the following selection factors: academic performance, social skills, leadership skills, or prior conflicts.

Although PBL is a student-driven process, there is a standardized protocol that each group needs to follow to...
ensure that the case is appropriately covered. Each group will need to establish a set of ground rules and standardized roles which will be used for the duration of the time they are learning together. Modifications to these roles may need to happen in response to feedback as the group progresses through PBL sessions (Ricanati 2014). The students can have assigned roles that can be taken up by each member on a regular basis to facilitate the group process. These roles may include, but are not limited to, Driver, Scribe, Researcher, and Timekeeper (Ricanati 2014).

The case is delivered through sequential disclosure, in the span of typically 3 sessions, with small increments of the case being delivered one at a time after the previous part has been discussed. This allows students using information revealed in the case parts to apply and use it for appropriate discussions (Jones 2006). The discussions must include differential diagnoses and formulation of questions that need to be explored (also known as “what we would like to know”; Ricanati 2014). As students work at their own pace through each case, an environment of student-driven learning is created and they solve the case problems as a group. At the conclusion of the session, the group develops a set of Learning Objectives (LOs) to help them better understand the basic science and other components of the case (Ricanati 2014). These objectives are divided among each group member for individual presentations in the following session.

During the next session (session 2), each student explains their assigned objective to the group. At the conclusion of all of the presentations, additional parts of the case are disclosed, and session 1 procedures are repeated. Session 3 begins with a similar series of individual presentations followed by the remaining case parts. After discussion, the students are provided a list of Case Objectives (COs) written by the case author(s) to ensure that every PBL group has a firm understanding of the important concepts linked to the case. These should have overlap with the LOs the students prepared. Following this, the students, as a group, develop a study-guide that addresses all of the COs for that case. This guide serves as a resource for later review.

By teaching medical students basic sciences in the context of clinical settings, PBL leads to outcomes such as increased physician competency after graduation, thus highlighting the effectiveness of PBL in preparing students for subsequent clinical practice (Al-Azri et al. 2014; Koh et al. 2008). As the students work through the case together, PBL also can improve their communication and interpersonal skills, soft skills which are also beneficial to their future careers.

Key features of the medical school PBL model (presence of a facilitator and a student driven process that includes student developed objectives that are revisited and later validated by PBL session objectives) can be applied to educational activities associated with other programs of study (Duch et al. 2001; Wilkerson and Gijselaers 1996; Woods 1994). This also includes sessions where students are provided with an article from the primary literature and discuss and deduce inferences from the article as a group (White 1993; 2001). It is strongly recommended to ensure that students understand the process before engaging in PBL. A “test run” activity can be performed to provide the students with experience and understanding of their roles and responsibilities. It is important to consider the logistics of implementing PBL at the undergraduate level given that many science courses involve large class sizes, providing additional infrastructure and scheduling challenges when working with such large student populations (Eberlein et al. 2008).

2) Developing a Facilitation Approach

Multiple factors can influence the success of the activity. These include selecting meaningful activities and/or questions, ensuring that the rationale of the activity is understood by the students, developing a thorough facilitation approach, and carrying out longitudinal recording and delivery of feedback. It is imperative to have a well-prepared facilitator for developing and implementing an effective PBL activity. The facilitation approach will be influenced by the context of the course including number of students, experience and background of the students, time availability, and infrastructure (tools, technology, furniture).

One of the most important elements of a successful PBL activity is that students feel a sense of accountability for participating in the assigned roles and responsibilities within their PBL group. This can be ensured by confirming that the ground rules for the group include being prepared for each session. Another way to ascertain accountability is by listening carefully to the group conversations and encouraging the discussions to stay on topic when necessary. Additionally, it is important to promote equitable contributions from each PBL group member. One of the most important aspects of facilitation in PBL is providing comprehensive and continual constructive feedback to the PBL group and to each individual member. In addition to providing feedback themselves, facilitators must also ensure that peer evaluations conducted within the group are consistent and specific. Table 1 was created in response to feedback from colleagues and summarizes the characteristics of an effective PBL facilitator.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Implementation Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Be an “expert learner” not a “content expert” or “source of answers”</td>
<td>Student: Dr. X (facilitator), what does this value mean in this case? Dr. X: This is a good point to research and explore. OR Does anyone from the group have any experience with this value and its relevance?</td>
</tr>
<tr>
<td>Be familiar with the case/activity</td>
<td>Dr. A (physiologist) facilitating a case related to infectious diseases has read the case and gone through the facilitator’s guide thoroughly.</td>
</tr>
<tr>
<td>Foster student discussion—encourage participation</td>
<td>During the session, when the facilitator is asked a question, it is best to deflect it back to the students to answer. Also, when students aren’t discussing a topic, it can be helpful to ask them questions and be comfortable with silence until they answer.</td>
</tr>
<tr>
<td>Be invested in the students’ learning and growth</td>
<td>Be on time and prepared. Ask them questions about their presentations. Take notes on their performance in the sessions. Meet with the students to discuss their performance and work with them to address any issues. Follow up on the issues as the students progress.</td>
</tr>
<tr>
<td>Ask leading questions</td>
<td>What evidence can you point to that supports your statement? Does everyone understand what this means? What else could be going on with this situation?</td>
</tr>
<tr>
<td>Establish a positive, supportive learning environment</td>
<td>Use “we” instead of “you. Exhibit patience with students. Provide praise when appropriate, along with critical feedback for improvement.</td>
</tr>
<tr>
<td>Embrace the uncomfortable silence</td>
<td>Provide an opportunity for the PBL group to address any pauses in discussions and take the lead in utilizing the allotted time productively. Do not jump in with answers as a facilitator. The students need to be the leaders of their learning.</td>
</tr>
<tr>
<td>Don’t be a dominant force in the room but, rather, a collegial presence</td>
<td>Don’t: I want you to start scribing all the facts in the case. Do: It will be great if we had a scribe assigned amongst the group to note the important facts in the case.</td>
</tr>
<tr>
<td>Encourage analysis of data provided and promote integration of information</td>
<td>Does this change in lab values indicate an alternative diagnosis? Does anyone want to explain that CT scan and what it could mean?</td>
</tr>
<tr>
<td>Promote appropriate resource use</td>
<td>Student: I found a video explaining the pathophysiology of this disease. Facilitator: What is the source of this video and when is the date of publishing?</td>
</tr>
<tr>
<td>Promote continuity/focus of the discussion and support group cohesion</td>
<td>When the group discusses a topic that was the topic of another case or a student’s presentation, the facilitator may ask “have we had any cases like this before?” OR “this sounds similar to a student’s presentation from last session. How might this be related?” It also may help for the facilitator to be mindful of group interactions and to ask the students in a confidential setting if they are having interpersonal issues with one another and then to mediate any situations that may exist.</td>
</tr>
<tr>
<td>Evaluate students</td>
<td>End of session feedback: The group can be more mindful regarding time management; scribe did a wonderful job getting facts up quickly! Weekly report evaluations: Student A can work on putting across his points to the group in a more concise and articulate manner.</td>
</tr>
</tbody>
</table>

*Table 1. Characteristics recommended for effective facilitation.*
3) Categories of Evaluations/Assessments

For PBL, it is important to have ongoing feedback and evaluation with regard to accomplishment of competencies by each student. In addition, multiple forms of feedback can be used to establish that continuum. Examples of feedback include:

1. Session Feedback: This is verbal feedback given at the conclusion of each PBL session and can be directed toward the individual as well as provided to all members when summarizing overall group performance. Each student provides this feedback, followed by the facilitator(s). Here, students provide any specific feedback which they feel comfortable sharing with the group.

2. Weekly Reports: These provide an analysis of each individual student during the week. This provides an opportunity for any additional comments and allows highlighting of areas that may need special attention.

3. Narrative self-reflection: Students perform self-evaluation using guided questions which are discussed during one-on-one meetings with the facilitator.

4. Facilitator(s)’ student evaluation: These questions are primarily identical to the narrative self-reflection questions, but from the facilitator’s point of view. This may contain added sections such as Medical Student Performance Evaluation (MSPE).

5. Mid and End of PBL Block Feedback: Facilitators have one-on-one meetings with each PBL group member to discuss their progress and self-evaluation of their performance. This time may also be utilized for discussing action items (goals for improvement created by the students with support from the facilitators that are then forwarded to new group facilitators for the subsequent PBL sessions). These typically happen at the mid and end of the assigned duration of the PBL group.

The above-mentioned examples of PBL evaluations can take the form of formative assessment or summative assessment, depending on the curriculum (Table 2).

---

<table>
<thead>
<tr>
<th></th>
<th>Formative Assessment</th>
<th>Summative Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal</strong></td>
<td>Monitor student learning to make suggestions on ways to improve their learning</td>
<td>Evaluate student learning and compare it to the student goals from formative feedback or to a particular competency.</td>
</tr>
<tr>
<td><strong>Timing</strong></td>
<td>During a learning activity</td>
<td>At the end of the learning activity</td>
</tr>
<tr>
<td><strong>Grading</strong></td>
<td>Provide students with low stakes feedback with low or no points assigned</td>
<td>Provide students with a moderate/high point value score or result</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>Can be provided several times during a course/activity etc.</td>
<td>Can be provided a few times over the course of the academic year, but only once per cohort of PBL students.</td>
</tr>
<tr>
<td><strong>Format</strong></td>
<td>Can cover many question formats</td>
<td>Can only use a limited number of question formats</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Provides a snapshot of learning/teaching during a session</td>
<td>Information can be used formatively: for example, students/faculty may use it to guide efforts and activities in subsequent courses</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>Session feedback, Mid-PBL block feedback, Narrative self-reflection questions</td>
<td>End of PBL block feedback, Medical student performance evaluation (MSPE), PBL content graded essays</td>
</tr>
</tbody>
</table>

*Table 2. Comparison between formative and summative assessments.*
4) Student Perspective
Apart from facilitator to student feedback, another vital aspect to be considered in optimizing the facilitation approach is for students to provide feedback to their facilitators. This allows for constant enhancement of the facilitation approach and the identification of targeted areas for improvement.

A key aspect to promote authenticity of the feedback from students is to ensure that the feedback is submitted anonymously. This allows students to feel comfortable in sharing their feedback since it is not possible for there to be negative consequences. A few recorded examples of student perspectives on the facilitation approach (comments provided by students to their PBL facilitators, shared anonymously by those facilitators) are included below:

- “She is the epitome of an optimal facilitator. She allows autonomy, facilitates creativity, and acts only as a guide to keep us on track, within the bounds of where we should operate within the PBL sessions.”
- “She is an excellent facilitator. She ensures that we are doing the vast majority of the work but does not hesitate to step in and promote a discussion. Her feedback for the group has always been helpful and specific. She is always available to lend an ear whenever necessary. I will miss having her as my facilitator.”
- “…If anything, the only improvement could be to step in when the conversations were really losing direction. There was one member of the group who often lacked focus in his presentations or his arguments that detracted from the group’s experience, and I think it would have been nice to have him hear that from the facilitator as well.”
- “She gave me incredible feedback during my mid-group written narrative feedback. She helped me focus on the things I had seen needed improvement, aided me in developing a plan to improve, and encouraged me and gave me feedback as we progressed”.
- “She was AWESOME! Her mid-block feedback was excellent and her feedback at the end of each case was excellent. We talked about ways to get an understanding of all students learning objectives in advance of the sessions, so I was able to ask more questions and be more engaged during the sessions, which I did achieve. She obviously had an interest in students’ growth!”

5) A Training Exercise for PBL Facilitation Feedback
To exemplify feedback implementation, it is helpful to have faculty engage in activities to model the behavior. For example, the following activity can be implemented through PBL facilitator training to help facilitators respond to unique situations that may arise and require feedback. Divide faculty into groups of 2-3 members and have them work through a set of different scenarios as a group (Table 3; Ricanati 2014). Approximately 10 minutes should be allowed for the provision of appropriate feedback for each scenario. At the conclusion of the 10 minutes, reconvene as a large group so that the responses of each group can be shared. This activity can be implemented either as part of an initial facilitator training program or provided to facilitators as a resource for faculty development.

| As a Facilitator, please provide feedback for following student scenarios |
|---|---|
| **Scenario** | **Notes** |
| **1** | Student A: contributes little, stares at the computer or at their notes |
| **2** | Student B: dominates conversations, intimidates other group members |
| **3** | Student C: one step behind the discussion, on their ANKI deck, last minute/a few minutes late submissions |
| **4** | PBL Group 1: sarcastic humor, inflexible, putting down ideas if disagreement in the group |

| As an Observer of the facilitation, please provide feedback for following faculty scenarios |
|---|---|
| **1** | Dr. G: appears sleepy, goes through emails, busy on device(s), provides generalized feedback |
| **2** | Dr. Q: content expert who appears passionate about their discipline, quick to jump in |

* Some of the activity scenarios were adopted and modified from (Ricanati 2014).

**Table 3.** Training exercise for PBL facilitation feedback.
Conclusions and Future Directions

An introduction to the PBL modality provides helpful tips on how to be an effective facilitator, including pointers related to feedback delivery and PBL assessments. Future faculty development regarding the facilitation approach should incorporate additional time dedicated to hands on learning and include ample examples and problem sets. An additional avenue to explore for the future would be to incorporate common topics in the basic sciences (anatomy and physiology, microbiology, molecular biology, etc.) and to identify ways to use PBL to cover those topics.

PBL can also be incorporated outside of professional schools in various undergraduate programs. For example, a lecture on human reproduction can easily be adapted to PBL modality by development of a case involving fertilization and gestation period for a young couple and include elements of associated complications and types of delivery options available for the couple. However, as long as the core concepts of PBL modality are maintained, (small group discussions, end of session peer feedback, etc.), slight modifications, (e.g., switching from 3-day cases to 1- or 2-day cases) may be made for a more seamless incorporation into settings outside of professional schools.

In summary, the PBL modality is a vital tool for diverse topics and educational settings and can provide opportunity for student-driven active learning sessions. Developing a facilitation approach for PBL requires critical thought and adaptability by educators to ensure successful implementation.

About the Authors

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Dr. Chasity O’Malley is an Associate Professor of Medical Education and Physiology at Boonshoft School of Medicine at Wright State University. Her research goals aim to improve the learning experience for students by helping them learn to study and interact with the material in meaningful ways and for faculty by helping guide them on implementing active learning into their classrooms and is a co-principal investigator for an NSF grant related to this work. She also is actively involved in promoting diversity through her funded research projects centered around enhancing training for medical students related to the LGBTQ population.

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An Introductory Framework of Problem-Based Learning (PBL) and Perspectives on Enhancing Facilitation Approaches


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The Use of a 12-lead Electrocardiogram (ECG) Laboratory Exercise for First Year Medical Student Learning

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Abstract
The normal 12-lead electrocardiogram (ECG) captures fundamental concepts covered in the principles of cardiac electrophysiology. First year osteopathic medical students recorded their own 12-lead ECG tracings in a laboratory session that also included completing a guided worksheet where they interpreted their 12-lead ECG results. Student feedback was solicited at the end of the course and the ECG lab exercise received positive feedback across several academic years. The data suggest that the student hands-on-experience of personal ECG recording and interpretation is a positive experience that may supplement first year medical student teaching and learning of cardiac electrophysiology. This paper summarizes the approach and teaching points that can be modified to fit various curricula. https://doi.org/10.21692/haps.2022.017

Key words: 12-lead ECG, cardiac electrophysiology, medical education, active learning

Introduction
The electrocardiogram (ECG) remains the gold standard for the diagnosis of abnormal cardiac rhythm (Pontes et al. 2018). Healthcare professionals from different backgrounds must learn the fundamentals from placing the electrodes to basic interpretation of the ECG. Utilizing the waveforms from the ECG is essential in explaining cardiac mechanics, one of the fundamental concepts in cardiovascular physiology. For medical students, the emphasis is placed on ECG interpretation, which complements the foundational knowledge acquired from understanding the principles of ECG. Therefore, a hands-on-exercise for first year medical students where they apply these principles in real-time is a mechanism by which medical educators can supplement student learning of basic cardiac electrophysiology. This in turn can enhance the foundations needed for ECG interpretation.

Cardiac electrophysiology and the basics of the ECG
The fundamentals of the activation of the heart (Klabunde 2017) can be taught using the ECG exercise in the first year of medical school. For example, differentiating between the layers of the heart, and the spread of the electrical activation can be explained by explaining the rational of an upright T-wave in various leads. The presence of Q and S waves during ventricular depolarization can also be explained using the principles of electrical activation of the heart and the principles of ECG. In addition, following the R-wave through the hexiaxial leads is a mechanism to demonstrate the spread of the wave of excitation across the heart. Collectively, this information can solidify the basic anatomical location of the heart along with the direction of electrical activation, and the principles of signal acquisition using ECG. It can also be used to emphasize the normal intervals and sequence, thus increasing diagnosis accuracy when given life-threatening ECGs to interpret.

Current evidence suggests that ECG interpretation skills are in need of attention to understand the learning gaps during training (Sibbald et al. 2014). Therefore, solidifying the foundational knowledge during the initial year of medical training can supplement current efforts aimed at improving diagnosis accuracy and interpretation (Krasne et al. 2020). While cardiac events during a cardiac cycle can be explained and understood without the principles of excitation, a true understanding of the physiology of the heart and, therefore, the basis of disease does not come without coupling ECG tracings to cardiac mechanics in a cardiac cycle. Therefore, learning the ECG is an application of the fundamental concepts in cardiac electrophysiology (Klabunde 2017).

Emphasized concepts using the 12-lead ECG
The student can take advantage of basic anatomy and physiology of the heart to explain lead placement. It is important to note that the student must first understand the principles of signal acquisition, which include concepts such as Ohm’s law. Therefore, describing a lead becomes important in helping the student understand the normal direction of electrical activity. Additionally, lead II and lead aVR can be used to demonstrate to students signal initiation and propagation, and is useful practice in completing the picture for a 12-lead ECG.

Once the student has mastered the basic concepts that include: 1) initiation of electrical activation, 2) propagation of electrical activation including the physical laws that
dictate the positive or negative deflection of an ECG wave, and 3) definition of a lead and lead placement on the chest wall, arms and legs, the student can then use the 12 lead ECG (frontal leads) to explain the propagation of the signal across the heart. For example, a student can apply these principles by explaining lead III, where the positive electrode is placed on the left leg and the negative electrode is on the left arm. The lead is crossing the chest wall, and the positive electrode is in the same direction as the electrical activation of the heart; therefore, normal lead III will have an upward or positive deflection. At this point, the student has mastered several concepts and is ready to learn that lead III can also be biphasic due to normal variations in the anatomical location of the heart in the chest cavity. This knowledge then will allow the student to apply the concepts of a normal axis quadrant, where normal has a wide range.

Another important application of the 12-lead ECG that reinforces the basic concepts of signal initiation and propagation is using the chest leads. For example, the anatomy and the direction of electrical activation can both be illustrated in the signal acquired by lead V1 and lead V6. The chest leads therefore are best used to demonstrate the microanatomical differences between right and left ventricles as well as the spread of depolarization, where the electrical activity moves down towards the apex before the signal makes its way to the back of the remainder of the heart. While the physiological differences in the activation of the heart are clearly presented in textbooks, the demonstration of a true understanding of the electrical heart would be best captured by giving the student the opportunity to experience lead placement and the real-time readout of a 12-lead ECG. These fundamental concepts can then be applied to explain the presentation of abnormal electrical events in the heart such as myocardial infarction and arrhythmias.

**Methods**

Approximately 200 students participated in the laboratory session. The students were split into 50 groups of 4 students each. Portable Cardiovit-FT1 touchscreen electrocardiograph machines (Schiller Inc., USA) were used for this activity (https://www.schillerus.com/product/product-solutions/ekgs/cardiovit-ft-1). A total of 10 machines were purchased by the department of biomedical sciences at West Virginia School of Osteopathic Medicine. The purchase of the ECG machines and testing of the functionality of the machines occurred approximately six months before they were used by students in the laboratory exercise. The year 1 cardiovascular course extends over 4 weeks. During the first week, the students were presented with traditional lectures and active learning material that covered fundamental concepts in cardiac electrophysiology (Table 1). By the end of the week, the students were asked to apply the material in the ECG laboratory exercise.

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
<th>Teaching Modality</th>
<th>Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ECG basics</td>
<td>LEC</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Normal ECG interpretation</td>
<td>LEC</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Common arrhythmias and rhythm strip</td>
<td>LEC</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>Vectors</td>
<td>LEC</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>ECG review of basics</td>
<td>DS</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>Basic interpretation of axis, rate, and rhythm</td>
<td>AE</td>
<td>50</td>
</tr>
<tr>
<td>7</td>
<td>ECG lab session</td>
<td>Lab</td>
<td>90</td>
</tr>
</tbody>
</table>

**Table 1.** Summary of teaching sessions and topics in the cardiovascular course associated with the content of electrophysiology given prior to the laboratory exercise. A total of 390 minutes is used for teaching foundational knowledge for electrophysiology and ECG basics. (LEC: lecture, AE: application exercise, DS: directed study)
The Use of a 12-lead Electrocardiogram (ECG) Laboratory Exercise for First Year Medical Student Learning

Prior to the exercise, the students were given a pre-lab quiz. The quiz questions were designed to familiarize the students with electrode placement. A recorded demonstration by the lab instructors was made available to the students prior to the laboratory exercise. Students were given 20 minutes to record their ECG. The students were instructed to complete the worksheet as a lab report assignment. The entire exercise was worth 1.5% of the course grade (Figure 1). The graded events included: the results from the pre-lab quiz, the 12-lead ECG record per student, and the results from the completed group laboratory worksheet. During the pandemic, this exercise was carried out following appropriate guidelines of social distancing and masking. To understand the usefulness of the ECG lab exercise in the learning of cardiac electrophysiology, the performance in ECG related content was evaluated. In addition, the course evaluation was searched for comments on the ECG laboratory session.

Results

From the academic years 2019/20, 2020/21, 2021/22, an average of 16/50 questions on the final examination of the course were mapped to the outcomes related to cardiac electrophysiology. Students had an average performance of (82.4% +/- 7.8) on those questions. Most importantly, a thematic analysis of student feedback from course evaluation was conducted and all the comments were positive (Table 2).

<table>
<thead>
<tr>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>“The EKG lab was particularly helpful in putting together the concepts of the electrical heart”</td>
<td>“Actually, having an EKG reading to hold in my hands allowed me to understand the leads better”</td>
<td>“The EKG lab was helpful, and I appreciated having my own EKG to look at”</td>
</tr>
<tr>
<td>“I thought that the EKG lab was very helpful.”</td>
<td>“The EKG lab was very interactive which was useful in my understanding of EKGs”</td>
<td>“I appreciated the EKG lab assignment it really helped me cement my understanding of EKG’s”</td>
</tr>
</tbody>
</table>

Table 2. Select student comments on the ECG laboratory session.
Discussion

This activity provides several opportunities for teaching points that can be used as a supplement to current didactic teachings (as done by this study) or modified slightly to fit a flipped-classroom activity. In a flipped classroom session, the didactic component would be modified to be learned at home by the student instead of attending the classroom sessions leading to the laboratory exercise. The teaching points summarized below were made during the laboratory activity and can be translated or modified to fit different curricula.

The ECG lead and membrane potential

One of the first concepts presented in the basics of the ECG is the acquisition of an electrical signal from the heart. Ohm’s law is used to help students understand that the current is equal to the change in membrane potential, thus the lead presents two poles that can capture that difference. The limb leads are bipolar and are easily explained. However, the augmented leads are derived from the limb leads and thus it takes an extra step to explain how they acquire the potential difference. A similar approach can be used to explain the chest leads. Once the students have understood that the ECG leads are simply different lenses at different angles, the student can now move on to use this knowledge to understand the totality of electrical activation of the heart.

Pacemaker and cardiomyocytes action potential

A fundamental concept that dictates the understanding of the ECG is the physiological difference in the action potential between the two types of cells present in the heart (pacemaker cells versus cardiomyocytes). The ECG can be used to reinforce the location of the sinoatrial node (atrial activation is first – a P wave is seen first), how the cells differ, where the signal from the pacemaker cannot be captured with classical 12-lead, and the specialization of each of the cells in their function (pacemaker to set the heart rate versus cardiomyocytes that are electrically coupled and provide the contractile response. Finally, the action potential of the cardiomyocyte can be overlayed with the wave forms and segments of the ECG.

The magnitude and direction of the spread of electrical activation

The limb leads can be used to explain the overall direction of the spread, where the placement of lead I and lead aVF give the student the opportunity to draw out a heart in two dimensions demonstrating the location of the heart in the chest cavity. This can be used to explain where the most positive R complex comes from that generally is seen in lead II. Lead II is in between lead I and lead aVF and the direction of the activation is spreading in that manner. This is a clear area where a student can fully understand the direction of depolarization of a normal heart. Clinical scenarios can be used to demonstrate when the spread of depolarization is blocked by dead/scared tissue, thus reinforcing the normal 12-lead ECG (i.e., ST-segment changes).

Waveforms of the ECG in relation to the anatomy and physiology of the heart

This is an area that can be demonstrated without the 12-lead, as all leads will capture all major waveforms. The variation in wave amplitude and presentation can then be attributed to the location/directionality of the electrical activation of the heart. For example, the P wave is most upright in lead II; that can be attributed to the location and direction of depolarization. Another example that can be used is the R wave; it is present in the chest leads with different amplitudes. This can be used to emphasize the direction of the spread where the activation of the posterior heart is best captured with the early chest leads. It can also be used to emphasize the structural difference in the left ventricle, which is necessary for cardiac performance.

The emphasis on ECG interpretation skills as part of medical training starts with understanding the fundamental concepts of cardiac electrophysiology. Using the 12-lead ECG to reinforce and demonstrate those concepts will equip students for better recognition of abnormal rhythms and abnormal electrical activity. It can also help the student to think about possible consequences from mutations in ion channels that are important for cardiac action potentials, leading to conduction abnormalities. The activity, direction and magnitude have physiological reasons that can be reinforced and demonstrated with a common diagnostic tool: 12-lead ECG.

While this lab does not cover all the details in the field and the students are directed to supplement their learning with additional resources and practice, it certainly provides the students with the hands-on-experience that will further solidify the fundamental concepts needed in their foundational sciences training. It is also an area where students can gain confidence in their understanding of fundamental concepts. The collective appreciation of student for the experience along with their satisfactory performance in the electrophysiology principles on the final exam suggest that using the 12-lead ECG lab as an application exercise can benefit student learning.

It remains possible that the students might perform in a similar fashion given the availability of simulation-based labs on the web to apply the same concepts. Future studies might benefit from conducting the analysis on similar questions without an ECG lab exercise component to the course. There are several limitations to this study including: 1) the questions used on the final exam were different between academic years, 2) the exercise is mandatory, and the lab activity is a graded event; and, finally, 3) variability in background preparation and learning style among students could have influenced the findings of this study.
Conclusions

The ECG laboratory activity was a positive learning experience for medical students in training. The exercise allowed the students to apply their classroom knowledge in a low-pressure environment, while still experiencing components of patient interaction with their peers. Social and communication skills are experienced with this exercise in addition to solidifying their foundational knowledge on cardiac electrical activity and cardiac mechanical function. This small group activity provides a demonstration of basic scientific concepts, along with engaging students with interpreting their own findings. This was well received by first year osteopathic medical students.

About the Author

Imaan Benmerzouga, PhD, is currently an assistant professor and course co-director of medical physiology in the Department of Foundational Sciences at the Kiran C. Patel College of Osteopathic Medicine. She teaches various topics including cellular physiology and the physiology of the endocrine, cardiovascular, and gastrointestinal systems. She previously held a similar position and was a physiology discipline co-coordinator at the Department of Biomedical Sciences at the West Virginia School of Osteopathic Medicine. She is a member of Human Anatomy and Physiology Society (HAPS).

Literature Cited


Appendix 1: Examples of Quiz Questions

Sample Pre-assessment quiz question
Where is the negative electrode placed for lead I?
- a. left arm (LA)
- b. left leg (LL)
- c. right arm (RA)**
- d. right leg (RL)

Where is the positive electrode placed for lead II?
- a. left arm (LA)
- b. left leg (LL)**
- c. right arm (RA)
- d. right leg (RL)

Sample worksheet question
After you print out your ECG (student sample Figure 2), calculate the following duration and intervals listed in the following table based on the AVERAGE from all leads. Use the extra space to show your work.

<table>
<thead>
<tr>
<th>Term</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR-interval</td>
<td></td>
</tr>
<tr>
<td>PR-interval</td>
<td></td>
</tr>
<tr>
<td>QT-interval</td>
<td></td>
</tr>
<tr>
<td>QRS duration</td>
<td></td>
</tr>
<tr>
<td>P-wave duration</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Figure 2. Sample of ECG print out obtained during the lab exercise*
Sample final examination question

A 30-year-old female presents to her primary care physician with complaints of palpitations. An ECG is ordered and reveals sinus tachycardia. The machine failed to calculate her heart rate. Which of the following can be measured to determine her heart rate?

- a. amplitude of QRS complex
- b. amplitude of T wave
- c. P-R interval
- d. R-R interval**
- e. S-T segment

**Rationale:** The answer would be distance between two R waves, because that represents one full cardiac cycle. Time is on the x-axis, while the y-axis represents the amplitude and that is force/direction of electrical activation not the time. The only options for time are R-R, PR and ST; the other options represent events during a cycle and not the completion of a cycle.
“Hold Your Breath and Bear Down”: Using Valsalva’s Maneuver to Explore Venous Variations in the Neck

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Abstract
The remarkable variation in superficial veins of the neck challenges anatomy students during cadaveric exploration. Despite frequently serving as cannulation sites, conduits for catheter placement, grafts following carotid endarterectomy, and a visual representation of central venous pressure, the jugular venous network and its variations are not well elucidated. A lack of health care provider awareness of venous variation may increase risk of clinical complications including ecchymosis, necrosis, and increased intraoperative bleeding. This study integrates an exploration of superficial venous variation in the necks of cadaveric specimens with a simple living anatomy exercise for anatomy students, aimed to shed light on anatomical variation and the typical venous patterns students may encounter in lab and clinically.

Cadaveric dissections were completed on twenty-four specimens to identify common variations from the textbook venous pattern of the neck and 3D renderings were created to help students better visualize anomalies. Next, students were instructed to perform the Valsalva maneuver to distend venous structures in the neck for visualization; photographs were taken to demonstrate the range of visible structures and patterns in living subjects. Four patterns were identified via cadaveric exploration and illustrated via three-dimensional (3D) renderings, and subject photographs were used to enhance learning by engaging students in the prediction of underlying structures. This activity deepened students’ appreciation for anatomical variation and promoted awareness needed for pre-interventional planning. https://doi.org/10.21692/haps.2022.018

Key words: anatomy teaching, gross anatomy education, living anatomy, anatomical variation, experiential learning, Valsalva maneuver, jugular veins

Introduction
Variations in venous drainage are frequent in humans, especially in the head and neck region. Because traditional anatomy atlases demonstrate only the most common anatomical pattern, students taking a cadaveric anatomy lab may struggle to recognize variations from the norm. Knowledge of frequently occurring variations is important to all anatomy students for identification purposes, and especially for those who may become health care providers. This would be particularly important if they were providing treatment in the head and neck regions of the body; this would include head and neck surgeons, oral and maxillofacial surgeons, anesthesiologists, and radiologists (Silva et al. 2016). The network of jugular veins is particularly important for catheterization, central venous pressure monitoring, and intravenous infusions; these veins may also be used for venous grafts (e.g., patch for carotid endarterectomies), or included in microvascular anastomoses for oral reconstruction (Gupta 2003; Silva et al. 2016; Singh 2020).

For example, the common facial vein has been used as patch material in carotid endarterectomies for decades and more recently recognized as an alternative route for catheter placement (Abeysekara et al. 2008; Bertha and Rabi 2011; Umek and Cvetko 2019). In addition to surgical needs, the increased administration of neurotoxins (Botox) and dermal fillers in the neck to relieve fine lines and wrinkles requires an acute awareness of superficial venous structures to avoid potential complications such as ecchymosis and necrosis (Lee et al. 2019). While numerous studies have reported isolated examples of venous anomalies in the neck, few have attempted to classify typical patterns (Bertha and Rabi 2011; Dalip et al. 2018; Sanyal and Joeaneke 2020).

Despite the heterogeneity of the vascularity in the neck, the traditional anatomical texts describe the typical superficial venous drainage as follows (e.g., Figure 3A as presented in the Results section). Venous drainage of the lateral scalp occurs via the superficial temporal vein, which unites with the maxillary vein to form the retromandibular vein within the substance of the parotid gland. The retromandibular
vein typically divides almost immediately into anterior and posterior divisions, with the anterior division uniting with the facial vein to form the common facial vein, which subsequently drains into the internal jugular vein. The posterior division of the retromandibular vein merges with the posterior auricular vein to form the external jugular vein, destined to drain into the subclavian vein in the root of the neck.

Numerous studies have described frequently occurring anomalies of this venous drainage pattern. For example, the external jugular vein is sometimes absent unilaterally or bilaterally, causing superficial veins to drain directly into the deeper internal jugular vein (Dalip et al. 2018; Paraskevas et al. 2014). There have also been cases noting duplication of the external jugular vein either unilaterally or bilaterally (Comert and Comert 2009; Ono et al. 2021). Additionally, even more variable is the anterior jugular vein, which may be a single midline vein or two parallel veins draining either into the external jugular vein or the subclavian vein (Lee et al. 2022; Nayak 2006). Finally, the common facial vein shows considerable variation in presence, length, and drainage tributary (Gupta 2003; Silva et al. 2016; Singh 2020). Few studies to date have reported typical lengths of individual's common facial vein, despite the necessary consideration when evaluating its potential for catheter placement or harvesting graft material (van Tonder et al. 2021). Given this remarkable variation in superficial venous drainage and the awareness required for clinical care, identifying veins of the neck and atypical variations is crucial, yet may be challenging, for anatomy students and clinicians alike.

Recent reports by Dee et al. (2021) and Georgakarakos and Fiska (2022) have revealed deficits in current anatomy teaching practices in instilling ‘authentic learning’ related to vascular anatomy, with the result that both undergraduate and resident students lack the clinically and surgically oriented knowledge of vascularity required to appreciate anatomical variations so that they can modify treatment plans when necessary. ‘Authentic learning’ in anatomical education requires intentional pedagogical approaches of high intrinsic value and clear translation to clinical application (Pawlina and Drake 2016). Surface anatomy is a fundamental component of health professional training to prepare students to visualize superficial anatomical landmarks in the living patient (Abu Bakar et al. 2022; Ganguly and Chan 2007). As an exercise to complement traditional anatomy pedagogy (lectures and laboratory), the incorporation of ‘living anatomy’ exercises enhances students’ abilities to solidify practical aspects of anatomical knowledge by observing, palpating, and manipulating their peers (Aggarwal et al. 2006; Jensen 2016; Johnson et al. 2012; Metcalf et al. 1982).

As one component of living anatomy, surface anatomy assessments can be done without any required equipment by simple demonstration, and the students themselves can serve as the subjects in the activity with their peers. This type of peer examination allows students to experience the inspection, palpation, and manipulation that a patient experiences, and may help them to develop empathy for others (Abu Bakar et al. 2022; Chinnah et al. 2011; Metcalf et al. 1982). When integrated into anatomical education, surface anatomy training has been shown to improve knowledge retention and assessment scores (Johnson et al. 2012). Clinically oriented surface anatomy exercises have long been recognized as important in anatomy education by increasing student confidence in translating knowledge to clinical skills (Aggarwal et al. 2006; Chinnah et al. 2011; Johnson et al. 2012). As rising costs in higher education create economic strain and limit resource expenditure, it is crucial to develop affordable or no-cost educational resources and activities to engage students (Price 2020).

One conventional maneuver that can be used to produce venous distension for better surface visualization is Valsalva’s maneuver, in which a patient is asked to forcefully attempt to exhale against a closed airway (Gupta et al. 2003; Pstras et al. 2016). Antonio Maria Valsalva, the Italian anatomist and physician, first described this technique in 1704 as a means to encourage purulent drainage from the ear (Kumar and Van Zundert 2018). Since then, the maneuver has been used clinically to evaluate autonomic dysfunction, identify and treat arrhythmias, and as a marker for heart failure (Junqueira, 2008; Kumar and Van Zundert 2018; Pstras et al. 2016).

This non-invasive technique causes an increase in intrathoracic pressure and reduced venous return to the heart, which in effect distends the neck veins allowing to better visualization of these procedurally important vessels (Pstras et al. 2016; Solanki et al. 2018). Although Valsalva’s maneuver has been a common method for producing venous distension in the clinical environment, it has not yet been described as an educational ‘living anatomy’ technique for students learning the superficial veins of the neck. As a simple, quick exercise, incorporating this ‘living anatomy’ experience for student observation may foster real-life application of venous anomalies while instilling an appreciation for the considerable anatomical variation encountered in clinical settings.
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Previous studies conducted on small cohorts of anatomical donors have revealed remarkable variation in drainage patterns, and considerable variation in the mere presence of all tributaries discussed therein (Dalip et al. 2018; Karuppiyah and Ponnambalam 2020; Ono et al. 2021; Silva et al. 2016). Given the wide variation reported, we aimed to contribute another data set to expand the reported variations in cadaveric specimens and classify frequently occurring superficial patterns. Furthermore, because previous studies that emphasize three-dimensional visualization of anatomy structures increases student understanding, we created 3D renderings of the most common variations we encountered for students to access outside the anatomy lab (Shaia and Elzie 2019). Because the common facial vein, in particular, has been of noted importance for clinical use with regard to catheter placement and graft potential, we also measured the length of each common facial vein encountered (Abeysekara et al. 2008). Finally, we introduced a simple living anatomy exercise to our anatomy students while exploring the superficial neck in cadaver lab, asking students to perform the Valsalva’s maneuver for their peers to observe ‘real-life’ variations and classify the visualized patterns if possible. Our goal was to shed light on the remarkable variation of superficial venous drainage in the neck both by cadaveric exploration and a living anatomy exercise in peer-to-peer observation, thereby elucidating a simple means by which students can gain an appreciation of both anatomical variation and awareness of non-invasive techniques to aid in visualization of anatomical variation.

Materials and Methods

The Institutional Review Board at the University of Nebraska Medical Center (UNMC) approved this study in 2020 (#0877-20-EP). Eighteen human cadavers, obtained through Nebraska’s Deeded Body Program with consent given for educational and research use, were dissected by UNMC health professional students and faculty and observed for data collection. Each hemi-specimen was recorded individually and for those specimens in which both sides were available, the two sides were inspected for symmetry. 15 left and 9 right hemi-specimens had viable, intact venous tributaries; the remaining specimens had incomplete or compromised dissections. After inspection of venous pattern, the length of each common facial vein (CFV) was measured using calipers by both researchers and the average length recorded. Simultaneously, all students currently enrolled in the Head and Neck Anatomy course participated in the living anatomy exercise by performing the Valsalva maneuver (taking a deep breath and holding it while bearing down to increase intrathoracic pressure). Twenty students volunteered and gave consent to be photographed while doing so. Photographs of each hemi-neck were taken for future inspection, capturing peak visibility of each subject’s distended superficial veins.

Results

Classification of cadaveric venous patterns

15 of the 24 specimens (62.5%) had a facial vein (FV) and anterior division of the retromandibular vein (ARMV) uniting to form the common facial vein (CFV) that drained into the internal jugular vein (IJV), the pattern most often depicted in anatomical texts; we therefore call this category 1 (Figure 1A). 14 of those 15 in category 1 had the typical union of the posterior division of the retromandibular vein (RRMV) joining the posterior auricular vein (PAV) to form the EJV. The remaining specimen in category 1 lacked an external jugular vein (EJV) entirely. Two specimens had a FV and ARMV combine to form the CFV which drained into the EJV; this pattern we call category 2 (Figure 1B). Six specimens lacked a CFV, and four of those showed the FV and RMV combining to form the EJV directly (no RMV divisions visible); this arrangement is category 3 (Figure 1C). Another single specimen had the FV and ARMV combine to form a lengthy CFV which ran adjacent to the AJV, both draining into the EJV at the root of the neck; this is called category 4 (Figure 1D).

While 22 of our 24 specimens fell into these four categories, we also observed two variants rarely reported; these are considered ‘other’ in Figure 2. One specimen had the FV and ARMV draining into the AJV; this pattern we call category 5. Six specimens lacked a CFV, and four of those showed the FV and RMV combining to form the EJV directly (no RMV divisions visible); this arrangement is category 3. Another single specimen had the FV and ARMV combine to form a lengthy CFV which ran adjacent to the AJV, both draining into the EJV at the root of the neck; this is called category 4. While 22 of our 24 specimens fell into these four categories, we also observed two variants rarely reported; these are considered ‘other’ in Figure 2. One specimen had the FV and ARMV draining into the AJV. The remaining single specimen had the FV and ARMV uniting with the UV independently. Six full cadavers had sufficient intact tissue structure to compare the left and right sides for symmetry. Of the six, four cadavers were symmetrical across midline in their venous patterns. The average length of the CFV was 34.0mm (range = 8 mm to 112 mm). Representative dissections are shown in Figure 1A-D, and Figure 2 summarizes the cadaveric findings by proposed category.
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Figure 1. Examples of cadaveric dissections demonstrating variations in superficial venous structures. A. Typical pattern of FV combining with ARMV to form CFV which drains into the INJ. B. Variation in which the CFV divides into two segments, both of which drain into the EJV. C. FV and RMV combine to form the EJV, with no communication to the IJV. D. Atypical long CFV runs adjacent to AJV to drain into the root of the EJV. (AJV = anterior jugular vein; ARMV = anterior division of retromandibular vein; CFV = common facial vein; EJV = external jugular vein; FV = facial vein; IJV = internal jugular vein; RMV = retromandibular vein)

Figure 2. Frequency of each venous pattern category in dissected cadaveric specimens (n=24).
Illustrations of observed cadaveric venous patterns

To allow student review of the venous variations outside of the anatomy lab, we asked a 3D medical artist to create 3D renderings based on our cadaveric observations. These 3D renderings provide directional orientation not easily interpreted on the cadaveric images as we do not photograph the faces of our donors per lab policy. The four frequently encountered superficial venous patterns of the neck that we assigned to categories 1-4 are illustrated in Figure 3. As described previously, category 1 is comprised of the typical union of the ARMV and FV to form the CFV which drains into the IJV (Figure 3A). Category 2 is the union of ARMV and CFV draining into the EJV, compromised of the PRMV + PAV (Figure 3B). Category 3 is an unbifurcated RMV joining the FV to become the EJV (Figure 3C). Category 4 is a more unique variant in which the long CFV runs adjacent to the AJV to drain into the EJV (Figure 3D).

Figure 3. 3D renderings of proposed venous categories, courtesy of Bill Glass, UNMC iEXCEL. A. Category 1: Traditional depiction of FV joining ARMV to form CFV which drains into IJV. B. Category 2: FV joining ARMV to form CFV which drains into EJV. C. Category 3: Undivided RMV joins FV to become EJV. D. Category 4: FV joins ARMV to form lengthy CFV, which alongside AJV drains into the root of the EJV. (AJV = anterior jugular vein; ARMV = anterior division of retromandibular vein; CFV = common facial vein; EJV = external jugular vein; FV = facial vein; IJV = internal jugular vein; RMV = retromandibular vein)
Visual observations of living subjects’ venous patterns

Subjects 1-11, 15, and 19 had visible, identifiable venous structures, whereas subjects 12-14, 16-18, and 20 did not demonstrate identifiable venous structures. Examples of subject photographs demonstrate the visibility of venous structures during maximum effort of Valsalva’s maneuver in Figure 4. We worked collectively in a large group (anatomy students and the researchers) to evaluate the images taken of the student volunteers and classified each based on our categories described above. Superficial landmarks were used to do so, and the discussion emphasized the anatomical relationships in superficial and deep planes that would help determine categories (our 3D renderings were particularly helpful here).

The subject in figure 4A has a visible EJV but no tributaries are identifiable. This subject most likely exhibits a Category 1 pattern. The subject in Figure 4B has no visible superficial veins. The subject in Figure 4C has a visible CMV draining into the EJV, which most likely demonstrates the Category 2 pattern. The subject in Figure 4D demonstrates a visible CFV running alongside the AJV, both draining into the root of the EJV, which most likely reflects the Category 4 pattern.

Figure 4: Examples of volunteers performing Valsalva’s maneuver to evoke jugular distension. Subject A demonstrates visible EJV, but no tributaries are visible. Subject B does not display prominent superficial veins during Valsalva’s maneuver. Subject C displays a visible CFV draining into the EJV. Subject D demonstrates a category 4 arrangement in which FV joins ARMV to form lengthy CFV, which alongside AJV drains into the root of the EJV. (AJV = anterior jugular vein; ARMV = anterior division of retromandibular vein; CFV = common facial vein; EJV = external jugular vein; FV = facial vein; IJV = internal jugular vein; RMV = retromandibular vein)
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Discussion

Identification of anatomical variations poses a challenge for anatomy students, yet the frequency with which vascular heterogeneity occurs in the head and neck region warrants recognition. Knowledge of the superficial veins of the neck is important for procedures such as central venous catheterization, myocutaneous flaps, carotid endarterectomies, and central venous pressure monitoring, and the awareness of typical variations is crucial in preventing intraoperative bleeding (Vani et al. 2019). Furthermore, the increasing popularity of minimally invasive aesthetic procedures of the neck, such as botulinum neurotoxin Type A and dermal filler injections, require providers to skillfully avoid such superficial veins in order to reduce associated risks such as ecchymosis and necrosis (Lee et al. 2019).

To date, few studies (excluding isolated case studies) have provided detailed descriptions of observed superficial venous anomalies of the neck (Dalip et al. 2018; Ono et al. 2021; Paraskevas et al. 2014). Our study provided depictions of frequently encountered variations, and describes a reinforcing, simple living anatomy technique that may synergize with cadaveric lab work by anatomy students exploring this territory.

Consistent with what has been reported by others, we observed most frequently the ‘textbook’ drainage pattern of the FV combining with the ARMV to form the CFV which then drains into the IJV, while the PRMV united with the posterior auricular vein to become the EJV.

Although variations from this pattern have been noted, few studies to date have used a cohort of cadavers to describe more commonly encountered venous variants. Here, we described 4 categories of superficial venous patterns uncovered through cadaveric dissection. While undoubtedly additional patterns exist, our aim was to shed light on the vascular heterogeneity expected in the superficial neck and to emphasize its clinical importance. As stressed by Georgakarakos and Fiska (2022), shedding light on the common anatomical variations future providers will encounter better prepares them for technical success in their treatment/care. By highlighting anomalies, anatomical educators reinforce the need for students to appreciate that no two individuals are identical and critical observation is necessary to anticipate individual variations and associated potential consequences clinically. Additionally, given the use of the CFV as patch material in neck procedures, the heterogeneity of presence and length (8mm to 112mm) of CFVs reported here is an important consideration for providers to be mindful of when treatment planning. Alternatives, including synthetic grafts or alternative autogenous tissue, may be required (Abeysekara et al. 2008).

The Valsalva maneuver is a common method to evoke venous distension for ultrasonic evaluation of the jugular veins. By forcefully exhaling against a closed glottis, the Valsalva maneuver increases intrathoracic pressure and subsequently reduces the preload to the heart, causing the veins of the neck to distend and protrude (Kumar and Van Zundert 2018; Pstras et al. 2016). The pronounced veins are more easily identified and discernable compared to the patient at rest, which allows for the healthcare provider to more easily locate the veins for assessment via ultrasound or for catheterization (Kumar and Van Zundert 2018). Incorporation of Valsalva’s maneuver in the anatomical educational setting provides ample opportunity for clinical correlations. We report for the first time its beneficial use in a living anatomy activity focused on identifying superficial veins of the neck.

Despite being a normal activity of daily living (i.e. straining when lifting, during defecation, playing a horn instrument), it is important to avoid unnecessary Valsalva maneuver in high-risk patients (or anatomy students) with conditions including retinopathy, artificial lenses, pre-existing coronary artery disease, valvular disease, or other known congenital abnormalities of the cardiovascular system (Pstras et al. 2016). As an alternative, Lewin et al. (2007) demonstrated humming to be as effective as Valsalva’s maneuver at distending the jugular venous system, so this technique may be used as needed. All subjects who participated in our exercise in which the Valsalva maneuver was employed to evoke superficial venous distension were healthy and relatively young in age (~22-38 years of age).

While some of our subjects did not demonstrate discernible venous structures at maximum effort in the Valsalva maneuver, this is to be expected with a variety of factors impacting visibility, including neck size. An extension of this activity could be introduction of vascular ultrasound to observe venous changes during the Valsalva maneuver, as first described by Dr. M. Attubato and colleagues in 1994 (Attubato et al. 1994). While the researchers’ compressed anatomy course schedule does not accommodate training in ultrasonography, the integration of point-of-care ultrasound in health professional training is increasing in popularity and may synergize well with this activity. Weiskittel et al. (2021) and Lufler and colleagues (2022) recently shed light on the potential benefits to the incorporation of ultrasound training in the anatomy laboratory which may highlight an opportunity to extend this living anatomy exercise in a clinically relevant way.

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Conclusions
To the authors’ knowledge, this is the first description of integrating initial learning of both ‘normal’ superficial veins of the neck and common variations with a simple living anatomy exercise to bring the anatomy to life. While venous anomalies have been reported in isolated case studies, our investigation of a cohort of cadavers reveals common patterns that may be encountered in both anatomical dissections and living individuals. Despite challenges such as reduced dedicated anatomical course time and financial strain, activities such as the Valsalva maneuver to elucidate venous variations in the neck offer a simple, no-cost means by which students can better engage with the content. Similarly, the opportunity to discuss physiological mechanisms at play during Valsalva’s maneuver may encourage integration and knowledge retention. Future studies aimed at understanding the impact of students’ exploration of venous variants and living anatomy experience on performance on lab practical exams and/or confidence in translating this awareness to future clinical application may help support its inclusion in the curriculum.

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