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Jackie Carnegie
Editor-in-Chief, *HAPS Educator*

Letter to the Editor: Core Concepts are a Guide not a Mandate

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We have proposed that a focus on core concepts can help students learn physiology (Michael et al. 2017) and can also provide a lens to examine instruction (Modell et al. 2015), assessment (McFarland et al. 2017; Semsar et al. 2019), textbooks, course prerequisites and other components of physiology education. We agree with Hull et al. (2017) that, "core concepts can help guide [emphasis added] the design of our curriculum, class activities, and assessment in order to facilitate lasting, meaningful, and transferable student learning." We reiterate that core concepts can provide frameworks to scaffold understanding of physiological processes, but we do not believe that the concepts or conceptual frameworks should be viewed as prescriptive.

A single sentence in recent article in the *HAPS Educator* prompted this letter and an opportunity for clarification. "Michael et al. (2017) provided a list of 15 core concepts that physiology education must [emphasis added] cover for students to effectively understand the functionality of physiological systems" (Tran 2022). This short note is intended to clarify our perspective on this issue.

Expanding on earlier work (Modell 2000), our group has written about physiology core concepts (Michael et al. 2009; Michael and McFarland 2011; Michael et al. 2017; Michael and McFarland 2020) and we have recently developed an online learning module for instructors (Michael and McFarland 2022), describing core concepts and how they might be used in teaching physiology. We have consistently attempted to communicate a number of messages that collectively describe our beliefs about how to use the core concepts in teaching physiology. These messages include the following:

(1) There is no one definitive list of core concepts for physiology. Rather, different groups or societies have and may continue produce different lists of core concepts (see Table 1 in Michael and McFarland 2020 and Table 1 in Semsar et al. 2019). Published lists of core concepts are not prescriptive, and they do not define the necessary content of a physiology course or physiology curriculum.

(2) Core concepts are tools for thinking about physiology and their use can facilitate student learning. The core concepts do this, in part, because they facilitate the transfer of learning (Michael 2022).

(3) It is unlikely that an instructor will choose to incorporate all of the 15 core concepts in their course. Rather, that instructor will select whichever of the core concepts will best serve the learning needs of their students. As Hull et al. (2017) noted, "Instructors can decide when and how to introduce their selected core concepts; introducing too many concepts at the beginning of the course may be overwhelming." The selection of core concepts to emphasize will vary from course to course and will be different in different curricula.

(4) There is no one right way to unpack a core concept to create a conceptual framework. However, we recommend the use of conceptual frameworks to support and align teaching, learning and assessment in a particular course or across a curriculum (Michael et al. 2017).

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In summary, the core concepts of physiology are guides to teaching and learning. These tools can be used when and where they will facilitate student learning. They are not a prescribed list of concepts that physiology students must use in order to master physiology.

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Joel Michael is a Professor Emeritus in the Department of Physiology & Biophysics at Rush Medical College where he taught medical physiology for many years. His physiology education research interests have included computers in physiology education, active learning, problem-based learning, and the uses of the core concepts of physiology. Jenny McFarland is emeritus faculty and former department chair of the Biology Department at Edmonds College where she taught human anatomy & physiology and introductory biology courses for more than 20 years. Her research in biology education focuses on core concepts for undergraduate physiology.

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The Impact of Mindset on Learning Behaviors and Learning Outcomes Among Health Professions Students

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Abstract

Mindset is defined as an individual's beliefs about their inherent characteristics and whether or not those characteristics can be developed. Growth mindsets have been associated with improved academic performance and resilience and may benefit students transitioning to graduate health professions education. This study examined the relationships between mindset, learning behaviors, and learning outcomes of first-semester graduate health professions students enrolled in a neuroanatomy course and examined other factors that may impact academic performance. Forty-one participants completed an electronic survey that included demographics and a mindset questionnaire. Learning outcomes, or grades, and learning behaviors, including office hour and tutoring session attendance, participation in bonus activities, and email correspondence with the course instructor, were collected. Based upon the mindset questionnaire, 10 participants were categorized as "strong growth", 28 participants as "growth with some fixed", and 3 participants as "fixed with some growth". There were no significant differences in mindset score based upon demographic characteristics. No significant correlations were found between mindset score, learning behaviors, or learning outcomes. Using a multivariable model, the factors that best predicted overall course grade were undergraduate grade point average (GPA) and number of prerequisite courses taken. While the lack of heterogeneity in mindset impacts the ability to determine potential relationships between studied variables, this study demonstrates that graduate health professions students largely have growth mindsets, perform well on academic assessments, including undergraduate coursework, and demonstrate frequent positive learning behaviors. Developing and reinforcing these behaviors as undergraduates may positively impact future success at the graduate level.
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Key words: mindset, neuroanatomy, learning outcomes, health professions, GPA

Introduction

As educators, understanding and facilitating learning is the core of our mission. Considerable effort has been dedicated toward understanding the implicit theories of the nature of intelligence, or the mindset theory. These theories state that intelligence is related to an individual's implicit belief of their ability. An incremental theory of intelligence is one in which an individual believes that their intelligence can be molded or increased whereas an entity theory of intelligence is one in which an individual believes that their intelligence is not controllable (Dweck and Leggett 1988).

Accordingly, mindset is the belief about one's innate characteristics and the ability of those characteristics to either be developed (a growth mindset) or remain fixed (a fixed mindset; Dweck 2006). Individuals with a growth mindset tend to seek challenges that promote learning, have high levels of persistence, and recognize that setbacks are part of the path to mastery. Individuals with a fixed mindset may avoid challenge or risk, have low levels of persistence, and avoid activities that would provoke negative judgment of their ability (Dweck and Leggett 1988).

Previous studies on the mindset theory have investigated the relationships between and overlapping nature among mindset and several variables associated with learning and performance, including grit and resilience. Grit can be defined as persistence for long-term goals despite the potential presence of challenges (Duckworth and Quinn 2009). Similarly, resilience can be defined as the ability to overcome adversity to achieve personal growth (Sanderson and Brewer 2017). Interrelationships between mindset and grit and resilience have been demonstrated in several studies (Barbouta et al. 2020; Bazelais et al. 2018; Calo et al. 2022; Hochanadel and Finamore 2015; Klein et al. 2017; Mosanya 2021; Wang et al. 2017) suggesting that in a learning environment, individuals with a growth mindset, greater

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grit or more resilience will have increased persistence even in the presence of challenges. In addition, a growth mindset has been associated with improved psychological well-being (Whittington 2017; Wolcott 2021). This further supports the notion that individuals with a growth mindset will be better prepared to handle adversity and the challenges associated with learning.

Further, several studies have investigated the relationship between mindset and learning strategies with results demonstrating that those with a growth mindset were more likely to utilize feedback, efficiently monitor errors, and generally use more effective learning strategies such as quizzing and teaching (Ng 2018; Williams 2020). Finally, a large majority of the studies investigating mindset have explored its relationship with academic achievement or performance. However, the findings related to this relationship are mixed. Several studies demonstrated that there was little to no evidence that a growth mindset positively affected academic achievement (Bahnik and Vranka 2017; Bazelais et al. 2018; Kustritz 2017; Sisk et al. 2018) with one study demonstrating a negative, though insignificant, association between mindset and academic achievement (Li and Bates 2020). Conversely, there are several studies that supported the positive relationship between mindset and academic achievement (Blackwell et al. 2007; Destin et al. 2019; Liu et al. 2018; Romero et al. 2014; Yeager and Dweck 2020; Yeager et al. 2019). Finally, academic achievement may also influence mindset in a reciprocal manner by which academic outcomes may create shifts towards a greater growth or fixed mindset and be particularly relevant and greater for students starting out with a tendency towards fixed attitudes (Limeri et al. 2020).

The impact of mindset on academic achievement has been investigated in many populations. However, its impact on academic achievement has not been widely studied within the graduate health professions, including within doctor of physical therapy students, master of occupational therapy students, and master of speech language pathology students (Williams and Lewis 2021). Of the studies that have specifically measured mindset in health professions' students, mindsets have largely skewed toward strong growth or growth with some fixed ideas (Calo et al. 2022; Kustritz 2021; Stuart and Wolcott 2021; Williams 2020; Wolcott et al. 2021).

Numerous studies have examined factors that predict graduate grade point average (GPA), clinical performance, and pass rates on board examinations within these professions. Consistently, undergraduate GPA, prerequisite coursework, graduate record examination (GRE) scores, and behavioral interview scores were found to be positively correlated with outcomes (Baus et al. 2021; Coleman-Salgado 2019; Gleeson et al. 2020; Kjelgaard and Guarino 2012; Lysaght et al. 2009; Pucillo et al. 2022; Roman and Buman 2019). Behavioral interviews evaluate a candidate's ability to utilize specific skills through their past experiences and are commonly assessed using a predetermined rubric of the demonstration of the skill through the candidate's response. However, these variables cannot necessarily predict how a student will respond to academic challenges in traditionally challenging science, technology, engineering and math (STEM) graduate coursework such as neuroanatomy (Javaid et al. 2019; Jozefowicz 1994). If mindset is associated with response to challenges, interventions to shift mindset towards growth may be worthwhile pedagogical strategies to implement as early as possible before or within matriculation into a graduate health professions program.

The purpose of this study was to examine the relationships between mindset, learning behaviors, and learning outcomes during an interprofessional neuroanatomy course taken in the first semester of a graduate health professions program. A secondary objective was to investigate the factors frequently examined in previous literature that predicted students' overall grade. The authors hypothesized that a greater growth mindset would be associated with increased occurrence of learning behaviors such as attendance at unstructured, professor-led office hours and higher achievement of learning outcomes as measured by examination and overall course grades.

Methods

This project was approved by the Moravian University Institutional Review board, protocol #22-0017, and informed consent was obtained from all participants.

Participants were recruited using convenience sampling. All first year doctor of physical therapy (DPT), master of occupational therapy (MSOT), and master of speech-language pathology (MSSLP) students were invited to participate. All students were enrolled in an interprofessional neuroanatomy and neurophysiology course. This course occurred during the first semester of their programs and was delivered and designed by the second author to provide a core syllabus of outcomes for the three health professions students. Each profession had a separate laboratory component that was discipline-specific. Potential participants were informed of the study by an outside party during their graduate program's orientation. They were provided with a short description of the study and a copy of the informed consent form. All students in the course were provided with the link to complete the survey and were told to only complete the survey if they completed the informed consent. The survey was open for three weeks, and reminders were sent on a weekly basis.

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Survey Instrument

The instrument used in this survey consisted of a demographic questionnaire and a mindset survey adapted from the work of Dweck (Dweck 2006). The survey instrument used was Qualtrics (version June 2022, Qualtrics, Provo, UT). The demographic questionnaire asked participants to provide information about their gender, ethnicity, race, size of undergraduate institution, type of undergraduate institution (private or public) and first-generation student status. Finally, the survey asked students to report which relevant prerequisite courses they completed prior to entrance into their respective graduate programs. Undergraduate GPA for each participant was obtained from the university.

The mindset survey consisted of twenty questions scored on a four-point scale which included the descriptors “strongly agree,” “agree,” “disagree,” and “strongly disagree.” The survey included items that address an “ability mindset” and a “personality/character mindset” and was constructed as either a “fixed” or “growth” mindset statement. Each question was scored based upon its construction as either a “fixed” or “growth” statement and the participants’ response. Scores ranged from 0 to 60 points and were divided into four categories: strong growth mindset (45-60), growth mindset with some fixed ideas (34-44), fixed mindset with some growth ideas (21-33), and strong fixed mindset (0-20). Despite its frequent use, there is no consensus on the reliability and validity of this instrument.

Outcome Variables

Learning behaviors of participants throughout the first semester of their graduate program, through their participation in the neuroanatomy and neurophysiology course, were collected by the course instructor. These behaviors included office hour attendance with the instructor, attendance during course-sponsored tutoring sessions, participation in bonus activities, and student correspondence about course material with the course instructor via email, exclusive of logistical questions. All of these learning behaviors were optional for students to attend. Educational outcomes, including examination grades and final course grades, were also collected by the course instructor. These data were provided to the primary investigator following the conclusion of the course. During the semester, all investigators were blinded to student participation in the research study.

Statistical Analysis

Learning behaviors were calculated as the sum of office hours and tutoring sessions attended, bonus activity participation, and email correspondences. Change scores between examinations were also calculated (e.g., $\Delta Grade_{12}$ = examination 2 grade – examination 1 grade). Normality of the data was assessed with the Shapiro-Wilk test and visual inspection of histograms. Frequencies were calculated for demographics variables, learning behaviors, and learning outcomes (examination grades, change scores between examinations, and overall grades).

Means and standard deviations (SDs) described normally distributed data; medians and interquartile ranges described non-normally distributed data. Differences between mindset scores and demographic variables were assessed with one-way analyses of variance (ANOVAs) and independent samples t-tests. Correlations between mindset scores and learning interactions and outcomes were assessed with Pearson’s r (normally distributed data) and Spearman’s ρ (non-normally distributed data). For the secondary objective of the study, correlations were used to assess the univariate relationships between predictor variables and overall neuroanatomy grades. Univariate correlations with $p < 0.20$ were retained for further analysis using multiple linear regression. Statistical significance was set to $\alpha = 0.05$. All analyses were conducted in SPSS (version 27.0, IBM Corp, Armonk, NY).

Results

Forty-one of 89 enrolled first-year graduate students participated in the study (Table 1). The participants had a mean ± SD undergraduate GPA of 3.4 ± 0.3 and had taken a mean ± SD of 5.4 ± 2.2 prerequisite courses. The mean ± SD mindset score was 41.8 ± 4.8 (range: 28-54). Based on these scores, 10 students were categorized as “strong growth,” 28 students as “growth with some fixed,” and 3 students as “fixed with some growth.” There were no significant differences in mindset scores based on demographics variables (Table 1).

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Variable	Descriptive Statistics	P-Value
Program	20 Doctor of Physical Therapy 13 Master of Speech-Language Pathology 8 Master of Occupational Therapy	0.868†
Gender	35 Females 6 Males	0.784‡
Race/Ethnicity	30 White 11 Non-white*	0.159‡
Undergraduate Institution Type	25 Four-year public 11 Four-year private (non-profit) 5 Four-year private (for profit)	0.292†
Size of Undergraduate Institution	7 <2,000 students 16 2,000-5000 students 6 5,000-10,000 students 10 >10,000 students	0.675†
First-Generation College Student	7 Yes 34 No	0.460‡

*3 Asian, 2 Hispanic/Latino, 1 Other, 5 Mixed
†One-way analysis of variance
‡Independent samples t-test

Table 1. *Participant demographics and differences in mindset scores.*

There were no significant correlations (Table 2) between mindset scores and learning behaviors or any learning outcomes (examination grades, change scores between exam grades, or overall course grade).

Variable	Central Tendency and Dispersion	Correlation with Mindset
Learning Interactions*	4 ± 3†	ρ = 0.18, p = 0.257
Examination 1 Grade	84.0 ± 21.8†	ρ = -0.03, p = 0.840
Examination 2 Grade	92.0 ± 14.0†	ρ = 0.11, p = 0.480
Examination 3 Grade	81.6 ± 11.4‡	r = 0.12, p = 0.472
$\Delta Grade_{12}$ (Exam 2–Exam 1)	3.0 ± 12.0‡	r = 0.17, p = 0.279
$\Delta Grade_{13}$ (Exam 3–Exam 1)	-1.8 ± 11.9‡	r = 0.11, p = 0.479
$\Delta Grade_{23}$ (Exam 3–Exam 2)	-4.8 ± 8.3‡	r = -0.09, p = 0.593
Overall Grade	89.8 ± 7.0‡	r = 0.09, p = 0.558

*Learning interactions are the sum of office hours attended, tutoring sessions attended, bonus activities participated in, and email correspondences
†Median ± interquartile range
‡Mean ± standard deviation

Table 2. *Learning interactions, learning outcomes, and correlations with mindset scores.*

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For the secondary objective of the study and based on univariate analyses, three variables were retained for multiple regression ($p < .20$): race/ethnicity, undergraduate GPA, and number of prerequisite courses (Table 3). In those univariate analyses, higher overall grades were associated with Caucasian participants, higher undergraduate GPAs, and more prerequisite courses taken. The multivariable model that best predicted overall neuroanatomy grade included undergraduate GPA and number of prerequisite courses ($R^2 = 0.234$, $F(2,37) = 5.652$, $p = 0.007$). The regression equation for this model was Overall Grade = 43.86 + undergrad GPA*11.43 + prerequisites*1.25. This model explained 23.4% of the variance in overall neuroanatomy grades.

Variable	Correlation with Overall Neuroanatomy Grade
Gender	$r_{pb} = 0.13$, p = 0.412
Race/ethnicity	$r_{pb} = 0.30$, p = 0.055*
Size of Undergraduate Institution	ρ = -0.05, p = 0.784
First-Generation College Student	$r_{pb} = 0.01$, p = 0.962
Mindset Score	r = 0.09, p = 0.558
Undergraduate Grade Point Average	r = 0.33, p = 0.037*
Number of Prerequisite Courses	r = 0.25, p = 0.126*
Learning Interactions	ρ = -0.18, p = 0.274

Abbreviations: r_{pb}, point-biserial correlation coefficient
*p < 0.20

Table 3. *Univariate correlations with overall neuroanatomy grade.*

Discussion

Many factors impact a student's success in a graduate health professions program. All programs create admissions standards with the attempt to enroll students most likely to complete the program and continuously review those standards when students do not achieve learning outcomes or degree completion. However, the admissions process cannot effectively capture how a student will respond to challenges or how well they believe they can improve when they face academic challenges or setbacks. A student with a growth mindset has been suggested to be more likely to respond to academic challenges by taking the steps necessary to improve their performance, such as attending office hours or review sessions (Dweck and Leggett 1988; Ng 2018; Williams 2020).

The results of this study did not reveal any statistically significant relationships between mindset and learning outcomes, nor any demographic factors related to mindset in a first semester neuroanatomy course of a graduate health professions program. The findings are consistent with previous studies that have also found no relationship between mindset and learning outcomes (Bahnik and Vranka 2017; Bazelais et al. 2018; Calo et al. 2022; Kustritz 2017; Sisk et al. 2018). All but three participants had a growth mindset (strong growth or growth with some fixed ideas), and none were classified as strong fixed, which may have limited the ability to capture the impact of a fixed mindset on learning outcomes and behaviors.

The mindset of students in this study, all healthcare trainees, is also consistent with previous studies (Calo

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et al. 2022; Stuart and Wolcott 2021). It is possible that students who are attracted to the health professions, specifically physical therapy, occupational therapy, and speech language pathology, either have or develop growth mindsets. A significant amount of the work of and training to become a healthcare provider is dedicated to motivating behavior change and facilitating a positive outlook toward rehabilitation. Even if they began their undergraduate careers with more fixed ideas, the students may have developed growth mindsets throughout their undergraduate careers as they experienced success in their prerequisite course work or overcame challenges in these courses, demonstrating the reciprocal relationship proposed in previous studies (Limeri et al. 2020).

Additionally, the exam grades among the participants were all above a mean of 80%, and the average overall course grade, which included quizzes and group assignments based on completion, was 89%, with all students passing the course. As previously mentioned, the literature examining the relationships between mindset and academic outcomes is mixed, with some studies finding strong relationships between growth mindset and positive academic outcomes and others finding no evidence. Any investigation into factors that influence learning outcomes must account for the vast differences in how those learning outcomes are measured, the level of transparency from the instructor on how to achieve these outcomes, the availability of support, and opportunities for feedback prior to higher stakes assessments. Student outcomes have also been shown to be related to the mindset of the instructor. A fixed mindset in an instructor was shown to have a disproportionately detrimental effect on underrepresented minority students in STEM education (Canning et al. 2019). More heterogeneity in both mindset and exam score than is present in this study may be needed to capture the relationships between mindset and academic achievement found in previous studies.

Mindset was also not correlated with learning behaviors such as emailing the instructor with questions, attending office hours, and attending tutoring sessions. A pilot study conducted in the summer of 2021 among only the DPT students (n=17) taking the same course found that mindset was also heavily skewed toward growth in this sample (88% strong growth or growth with some fixed, no strong fixed). This investigation found significant correlations between mindset and office hours attendance, attendance at exam reviews and the final examination, but not with overall course grade or the first 2 exams, suggesting that mindset may be related to learning behaviors that "pay off" at the end of the course (Elinich et al. 2021). By expanding the investigation to capture more types of learning behaviors and increasing the study population, the authors hoped to increase heterogeneity in mindset scores and reveal any significant relationships between mindset, learning outcomes and learning behaviors, and did not anticipate the same trend in mindset scores.

It is worth noting that all the participants participated in at least two, and up to 13 unique learning behaviors, with an average of 4 ± 3 interactions across the participants over a 10-week course, or close to an average of once every 2.5 weeks. Given the long-standing debate about the usefulness of office hours and the reasons students tend not to participate in them, this was an encouraging result. Previous studies examining why students do not ask for help, usually in the form of office hour attendance, have cited a lack of usefulness and not knowing what questions to ask as common reasons for not seeking assistance (Griffin et al. 2014). In the interprofessional neuroanatomy course, students were provided with weekly formative quizzes as well as study guides and were strongly encouraged to break down each quiz question until they could justify their answers and explain them to an instructor or peer. Thus, most of the email correspondence, tutoring and office hour attendance was spent directly working through difficult problems that students were aware they needed to overcome. This help-seeking behavior is consistent with previous students that have shown that growth mindset is related to feedback-seeking and improved performance on formative assessments (Ng 2018; Stuart and Wolcott 2021; Williams 2020; Yan et al. 2014).

The authors also sought to determine what factors predict a student's overall neuroanatomy grade. Consistent with the literature that examines graduate anatomy and neuroanatomy courses, undergraduate GPA is a consistent predictor of performance (Coleman-Salgado 2019; Gleeson et al. 2020; Kjelgaard and Guarino 2012; Lysaght et al. 2009; Pucillo et al. 2022; Roman and Buman 2019). The number of prerequisite courses was also a significant predictor in the model of performance. Among the three groups of health professions students in this study, prerequisite requirements varied greatly. The DPT students are required to take over twice the STEM courses for admission compared to MSOT and MSSLP students with the result that the DPT students averaged significantly more of these courses taken than the MSOT and MSSLP students (6.8 ± 1.4 versus 4.5 ± 2.4and 3.8 ± 1.6, respectively). Previous studies have shown that prerequisite coursework performance predicts graduate coursework performance, but the results are mixed in terms of the number of courses, specific content of courses, or overall science GPA (Baus et al. 2021; Halberstam and Redstone 2005; Pucillo et al. 2022, Roman and Burman 2019; Sylvan et al. 2020). Prerequisite coursework may provide students with a foundational knowledge base upon which to build their graduate coursework, or simply to help develop the skills to be successful in a science course at the graduate level. However, the benefits of this prerequisite coursework may be limited to those initial basic science courses in a curriculum (Coleman-Salgado 2019). Furthermore, success within these courses may encourage a growth mindset, as models of a feedback loop between mindset and academic achievement have been proposed (Limeri et al. 2020).

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Limitations

This study helps to address a gap in the literature on mindset and its impact on learning outcomes among graduate healthcare professions students. It incorporated learning behaviors such as completion of bonus activities, attendance at tutoring sessions, emails, and office hours in addition to grades, as well as examination of the change scores between exams. The study was limited by the lack of variety in mindset scores as well as a tendency for all participants to achieve high scores on the exams and high overall course grades. There are inherent limitations to survey-based research including measuring variables of interest at only one point in time, the potential for self-report bias, and the potential for variable interpretation of survey questions. Recruitment for the study occurred during what could be a potentially overwhelming time for the incoming graduate student, and this may have contributed to the 47% participation rate. The participants were predominantly white, female, and at least second-generation college students, which limits the generalizability to larger, more diverse populations of students. The authors were also unable to capture any other learning behaviors such as watching videos, meeting with peers, or the myriad other factors such as time available to study, social support, and health challenges that may have contributed to their grades.

Conclusion

This study found that graduate healthcare trainees overwhelmingly possess a growth mindset, but the results of this investigation are unable to associate that mindset with their learning behaviors or learning outcomes. Learning outcomes in graduate education continue to be predicted by undergraduate GPA and prerequisite coursework. Therefore, the results of this investigation suggest that interventions to shift mindset would not have a beneficial effect on learning outcomes or behaviors in this population. However, as there are interrelationships with mindset and other variables such as grit and resilience, it may be worth investigating the impact of these variables on learning outcomes and learning behaviors in future studies to learn how instructors can facilitate optimal learning strategies and outcomes in health professions students to maximize both their academic and professional success. Future studies should consider re-administering the mindset instrument at the end of a course to see if learning outcomes cause shifts in mindset, and which students are more vulnerable to shifts towards a fixed mindset when they encounter challenges. Finally, it may be worthwhile to examine the relationship between mindset and learning outcomes for students further into their graduate programs, rather than at the onset of their graduate studies, after they have potentially had more academic challenges to overcome.

About the Authors

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Appendix 1: Mindset Quiz

To what extent do you agree or disagree with these statements?

(Strongly Agree Agree Disagree Strongly Disagree)

1. Your intelligence is something very basic about you that you can't change very much. ___________
2. No matter how much intelligence you have, you can always change it quite a bit. ___________
3. You can always substantially change how intelligent you are. ___________
4. You are a certain kind of person, and there is not much that can be done to really change that. ___________
5. You can always change basic things about the kind of person you are. ___________
6. Music talent can be learned by anyone. ___________
7. Only a few people will be truly good at sports – you have to be "born with it." ___________
8. Math is much easier to learn if you are male or maybe come from a culture who values math. ___________
9. The harder you work at something, the better you will be at it. ___________
10. No matter what kind of person you are, you can always change substantially. ___________
11. Trying new things is stressful for me and I avoid it. ___________
12. Some people are good and kind, and some are not – it's not often that people change. ___________
13. I appreciate when people, parents, coaches, teachers give me feedback about my performance. ___________
14. I often get angry when I get feedback about my performance. ___________
15. All human beings without a brain injury or birth defect are capable of the same amount of learning. __________
16. You can learn new things, but you can't really change how intelligent you are. ___________
17. You can do things differently, but the important parts of who you are can't really be changed. ___________
18. Human beings are basically good, but sometimes make terrible decisions. ___________
19. An important reason why I do my school work is that I like to learn new things. ___________
20. Truly smart people do not need to try hard. ___________

Key

1. ability mindset – fixed
2. ability mindset –growth
3. ability mindset – growth
4. *personality/character mindset - fixed*
5. *personality/character mindset – growth*
6. ability mindset – growth
7. ability mindset – fixed
8. ability mindset – fixed
9. ability mindset – growth
10. *personality/character mindset - growth*
11. ability mindset – fixed
12. *personality/character mindset – fixed*
13. ability mindset –growth
14. ability mindset – fixed
15. ability mindset – growth
16. ability mindset – fixed
17. *personality/character mindset – fixed*
18. *personality/character mindset –growth*
19. ability mindset – growth
20. ability mindset - fixed

Scoring

Growth Questions

1. Strongly agree – 3 points
2. Agree – 2 points
3. Disagree – 1 points
4. Strongly disagree – 0 point

Fixed Questions

1. Strongly agree – 0 point
2. Agree – 1 points
3. Disagree – 2 points
4. Strongly disagree – 3 points

Strong Growth Mindset = 60-45 points
Growth Mindset with some Fixed ideas = 44-34 points
Fixed Mindset with some Growth ideas= 33-21 points
Strong Fixed Mindset= 20-0 points

Adapted from: Dweck, C. S. (2006). Mindset: The new psychology of success. New York: Random House Inc.

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Engagement in the Undergraduate Science Course: Lessons Learned about Participation and Distraction from the Remote Classroom

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Abstract

The COVID-19 pandemic has left very little unaltered, education included. Institutions encountered an almost immediate transition to remote learning to prevent disease transmission. Because most students and instructors alike were unfamiliar with remote learning, challenges quickly arose and have unfortunately lingered longer than most had hoped. In this study, we investigated the effects of remote learning on student engagement and perceived success in face-to-face undergraduate science courses from both the student and instructor perspectives. We attempted to identify the major distractors as well as strategies which increased engagement for students. Analysis revealed that students were less likely to engage in their remote science classroom when compared to their previous face-to-face classrooms with no significant differences in perceived engagement or success between class standing or age of the students. Students identified the strongest remote classroom diversions as other distractions on the internet and mental health issues. The most engaging factors in the remote classroom were instructor enthusiasm and questions presented by the instructor. From the instructor perspective, they found it more difficult to connect with students and found students engaged less in group discussion in remote courses when compared to their face-to-face in courses. Our data reveal differences in engagement and perceived success from the student and instructor perspective in remote science courses which were offered previously in a face-to-face format. Lessons learned from this study will not only assist in improving future remote courses but will assist in student engagement in the undergraduate science classroom overall. https://doi.org/10.21692/haps.2023.004

Key words: remote learning, active learning, engagement, success

Introduction

COVID-19 changed almost every aspect of human life, including education. The almost immediate change in course delivery format has greatly impacted both educators and students. Due to social distancing guidelines, classroom capacities were greatly reduced while the pandemic forced most to engage in remote learning on videoconferencing applications like Zoom. While some have been greatly impacted by this new format, leading to a decline in academic performance, others have found benefit in the ease of use and flexibility. Regardless of the preferred format, this new remote delivery method has impacted engagement and understanding, particularly in undergraduate science classrooms which were traditionally taught face-to-face. We aimed to study both quantitatively and qualitatively from teacher and student perspectives.

In the remote learning environment, it can be challenging for students to stay engaged in the classroom and motivated throughout the semester. Students in face-to-face classrooms had higher rates of motivation when compared to students in remote classrooms (Raes et al. 2020). In addition, students in face-to-face classrooms received higher in-class quiz scores than those in virtual classrooms (Raes et al. 2020). Students were asked to reflect on their top concerns regarding remote learning. Those ranking highest were demotivation, access to reliable internet, access to technology, and influence of the home environment (de Souza et al. 2020). More specifically, STEM students reported higher dissatisfaction with remote learning during the pandemic when compared to their non-STEM peers (Barber et al. 2021). Of particular importance, first-generation students and under-represented minority students felt they had less time to focus on schoolwork with higher expectations in the home and other responsibilities (Barber et al. 2021). While some issues that arose during remote pandemic learning were obvious such as internet connectivity and functioning issues, other issues such as communication challenges between instructors and students were more nuanced (Katz et al. 2021). It is important to note, however, that challenges such as communication and

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discrepancy between under-represented minority students existed in remote learning before the pandemic, and the pandemic may have exacerbated these issues. Overall, it is clear from emerging studies that remote learning poses serious challenges for educators, particularly in motivating and connecting with students (Daniels et al. 2021; Petillion and McNeil 2020; Wester et al. 2021).

Less research has been published on science-specific curriculum and the impact of remote learning on these face-to-face courses, especially labs. Graduate medical students from 13 medical schools felt that certain clinical aspects were not achievable via virtual learning and had subsequent concerns about preparedness in their field (Alsoufi et al. 2020). Undergraduate microbiology students attended labs offered in both remote and in-person formats. While students found remote activities convenient, an overwhelming majority of students desired a hands-on component to the lab (Brockman et al. 2020). This data suggests that even if pandemic remote learning ceases, educators should maintain invested in best strategies for remote learning engagement as it may provide an important modality, in part, for future students.

While many students have been previously accustomed to remote learning, particularly non-traditional students, the pivot to online learning was abrupt and disruptive to many. Students were required to engage in a format that they would not have likely chosen for themselves. First-time remote students during the pandemic revealed that they felt there was less flexibility in their remote courses alongside a heavier workload (Trout 2020). Concerns were not the same for all courses. These students found that remote learning worked well for general education classes but not for core courses in their major (Trout 2020). Of particular importance, these students felt that difficulty in communication and lack of interaction have negative effects on their motivation in the remote courses (Trout 2020). This highlights a particular concern for engagement in science courses.

While the pandemic and disruptive learning will not last forever, remote and online learning will continue. According to the National Center for Education Statistics, in Fall 2018, over 6 million students had enrolled in at least one distance education course at degree-granting postsecondary institutions, which had increased from previous years (U.S. Department of Education 2019). In Fall 2019, this number rose to over 7 million students and with the pandemic, Fall 2020 remote course enrollment jumped to over 14 million (U.S. Department of Education 2021). This necessitates the need to better understand engagement in the remote classroom from both the student and instructor standpoint, which likely lead to perceived and actual academic success. As online enrollment and interruptions may continue, lessons learned from this study not only guide success in the remote classroom, but in the face-to-face classroom as well.

Materials and Methods

Data Collection and IRB Approval

We conducted two surveys from February to April 2021. These self-administered surveys were completed by using an online software (Qualtrics, Provo, UT) following informed consent. The surveys were distributed via email link to either students or instructors participating in undergraduate core biology, chemistry, or physics courses involved in remote learning which were previously offered in-person. The survey contained Likert scale, ranking, demographic, and open-ended questions. The survey did not collect any identifying data to ensure participant confidentiality. Surveys responses were removed from participants who did not verify via questionnaire that they enrolled in one of the described courses above. This project was approved by the Webster University Institutional Review Board (IRB approval number SP2129) and informed consent was obtained from all participants.

Statistical Analysis

Data was collected through Qualtrics (Qualtrics, Provo, UT). We used descriptive statistics, particularly frequencies and percentages, to examine mean participant responses. For ranking data, we utilized the mode response and reported percentages. In addition, we compared group means via one-way ANOVA utilizing IBM SPSS Statistics.

Results

Basic Student Demographics

We sought to describe student perceptions towards remote learning in undergraduate biology, chemistry, and physics courses. We received 36 surveys which met our exclusion criteria (enrolled in Essentials of Biology I/II, Anatomy and Physiology I/II, General Chemistry I/II, or General Physics I/II courses in Fall 2020 or Spring 2021 that met remotely on Zoom). Participants were predominately upperclassman and between 18-25 years old (Table 1).

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Class Standing	Percent Response (n)	Age	Percent Response (n)
Freshman	8.3% (3)	18-25	97.2% (35)
Sophomore	27.8% (10)	26-33	2.8% (1)
Junior	30.6% (11)	34-41	0% (0)
Senior	33.3% (12)	42+	0% (0)

Table 1. *Student survey demographics describing class standing and age. n=36*

Association of Engagement in Remote Undergraduate Science Classrooms with Age or Class Standing

We surveyed students to determine their perceived engagement in undergraduate science courses which were held remotely when compared to their previous face-to-face experiences. When participants were questioned how likely they were to respond to their instructors' questions in the remote classrooms we found that most students (63.9%) felt less likely to respond when compared to a face-to-face setting (Table 2). When we compared responses by class standing, we found no statistical difference in responses between groups, thus class-standing had no determination on whether students were more or less likely to respond *(p=0.510, data not shown*). When participants were questioned how likely they were to ask for help or clarification in the remote classrooms we found that most students (55.6%) felt less likely to ask for help/clarification when compared to a face-to-face setting (Table 2). Similarly to the response question, we found no statistical difference in responses from different classes *(p=0.585, data not shown*). Group discussions have been utilized to improve connection and engagement in the remote classroom, thus we asked participants how likely they were to participate in group discussions in the remote classrooms when compared to a face-to-face classroom. We found the majority of students (72.2%) felt less likely to participate when compared to a face-to-face setting (Table 2). In addition to questioning the likelihood of their actions, we directly asked how engaged students felt in these remote classrooms. We found that the majority of students felt less engaged (83.3%) in the remote classroom when compared to their face-to-face classroom engagement (Table 2). It has been suggested that increased engagement can result in increased success. While we did not measure assessment scores, we did ask the students about perceived success. Interestingly, a large number of students (44.4%) felt about the same when comparing their perceived success in the remote vs the face-to-face classroom. Still, a large number of students (38.9%) felt less successful in the remote classrooms (Table 2). When comparing class standing for their perceived engagement and success survey items, we observed no statistical difference between the remote and face-to-face classroom *(p=0.146, p=0.230 respectively, data not shown*).

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Survey Item	Less Likely (1)	About the Same (2)	More Likely (3)	Mean (±SD)
How likely are you to respond to your instructor in the remote classroom when compared to the traditional classroom?	63.9%	27.8%	8.3%	1.4 (±0.7)
How likely are you to ask for clarification in the remote classroom when compared to the traditional classroom?	55.6%	33.3%	11.1%	1.6 (±0.7)
How likely are you to participate in group discussion in the remote classroom when compared to the traditional classroom?	72.2%	25.0%	2.8%	1.3 (±0.5)
How likely are you to be engaged in the remote classroom when compared to the traditional classroom?	83.3%	8.3%	8.3%	1.3 (±0.6)
How likely are you feel successful in the remote classroom when compared to the traditional classroom?	38.9%	44.4%	16.7%	1.8 (±0.7)

Table 2. *Student survey addressing perceptions on engagement and success in the remote undergraduate science classroom when compared to face-to-face classrooms. n=36*

Student Ranking of Distractors and Promotors of Engagement

We were interested in exactly why engagement was lower in remote classrooms when compared to in person science courses. We implemented a question which had participants rank their greatest distractors in the remote science classroom (Figure 1). We found that 46% of students felt that other distractions on the internet were the major contributing distractor in remote classrooms (Figure 1). The next major contributing factor was stress, anxiety, and/or other mental health concerns (28%). The mode response was "Other Distractions on the Internet" (Figure 1).

Factors which ranked lowest on the scale and thus not likely to play a role in decreased engagement were the lack of authority or personal accountability (29%) in remote classrooms, other people in the learning area (17%), other obligations outside of the course (11%), and interestingly stress, anxiety, and/or other mental health concerns (14%) (Figure 2). While many reported mental health concerns as a major distractor, others felt that it played no role at all. Interestingly, it was the most polarized response, being high in both the highest and lowest ranked distractor (Figure 1-2). The mode for this least likely contributing factor to distraction was "Lack of Authority or Personal Accountability" (Figure 2).

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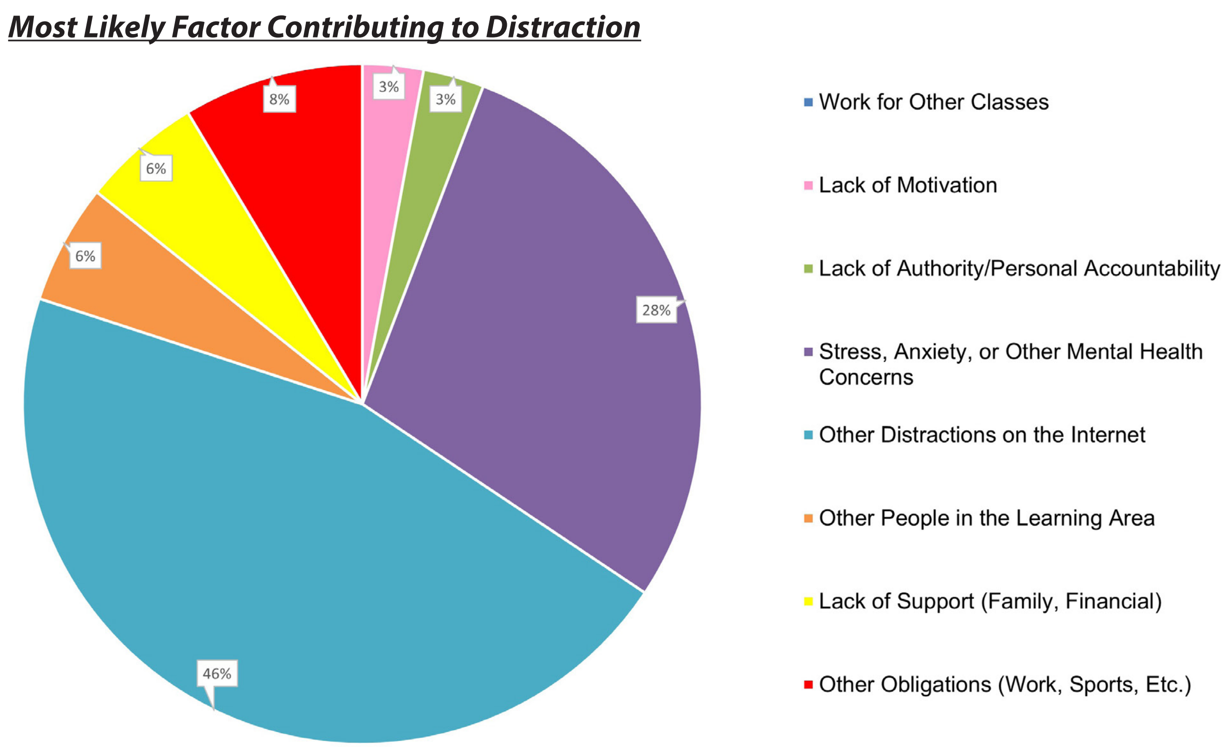

Figure 1*. Student survey of the largest distractors in the remote undergraduate science classroom when compared to face-to-face classrooms. n=35*

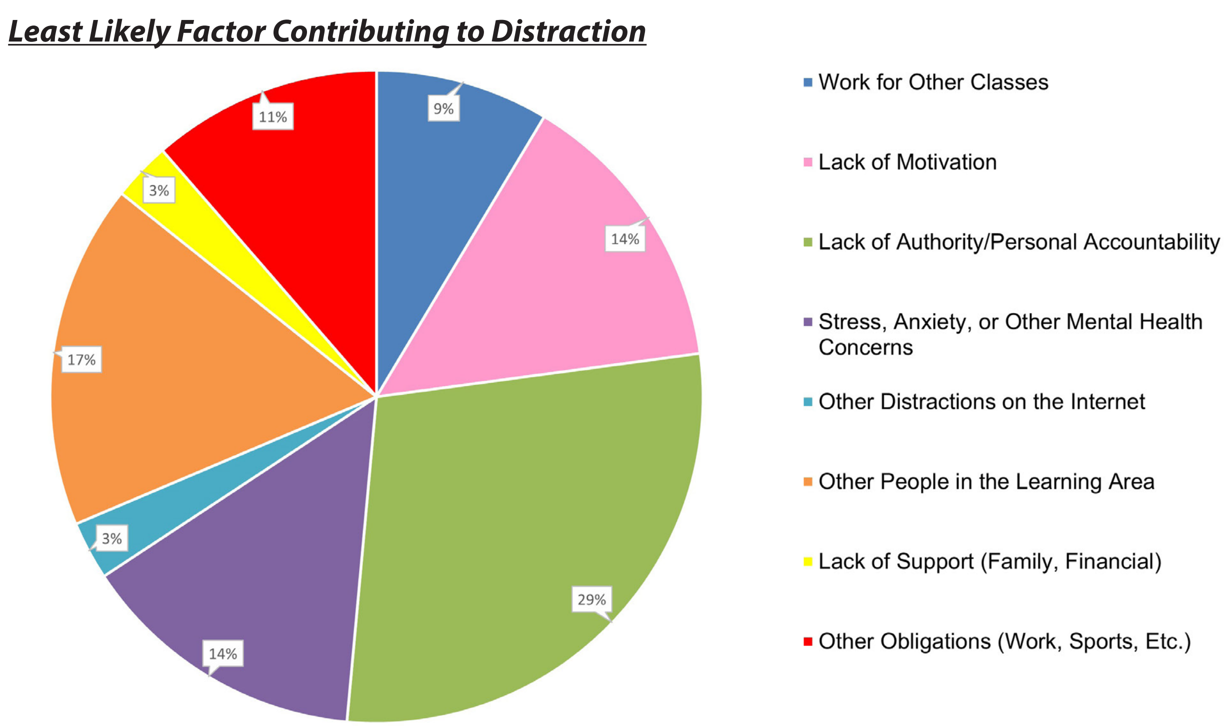

Figure 2*. Student survey of the least likely distractors in the remote undergraduate science classroom when compared to face-to-face classrooms. n=35*

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We also implemented a ranking survey question which focused on the largest promoting factors for engagement (Figure 3). We found the most likely factors contributing to student engagement in the remote science classroom were instructor enthusiasm/passion (46%) and questions asked by the instructor (27%) (Figure 3). The mode response for greatest promoter of engagement was “Instructor Enthusiasm/Passion” (Figure 3). The least effective strategies for were much more variable. They included the requirement by the instructor to engage (24%), breakout rooms (15%), and instructor passion (21%) ranking least likely to contribute to engagement (Figure 4). Again, instructor passion was one response that was polarizing; however it was two times more likely to be considered a contributing factor to engagement (Figures 3 and 4). The mode for least likely factor to contribute to remote classroom engagement was “requirement by the instructor” to engage such as keeping the camera on or participating in a response (Figure 4).

An open response question asked students if there were any factors which strongly contributed or hindered their success in their remote science courses. While no common themes emerged, students mentioned that flexibility and the ability to better manage time contributed to success while factors such as excessive screentime, additional coursework, and lack of teacher engagement hindered their success. We also asked students for their suggestions for future remote learning. A common theme was the request for increased engagement from the instructor, specifically asking for more group discussions, games, breakout rooms, and communication.

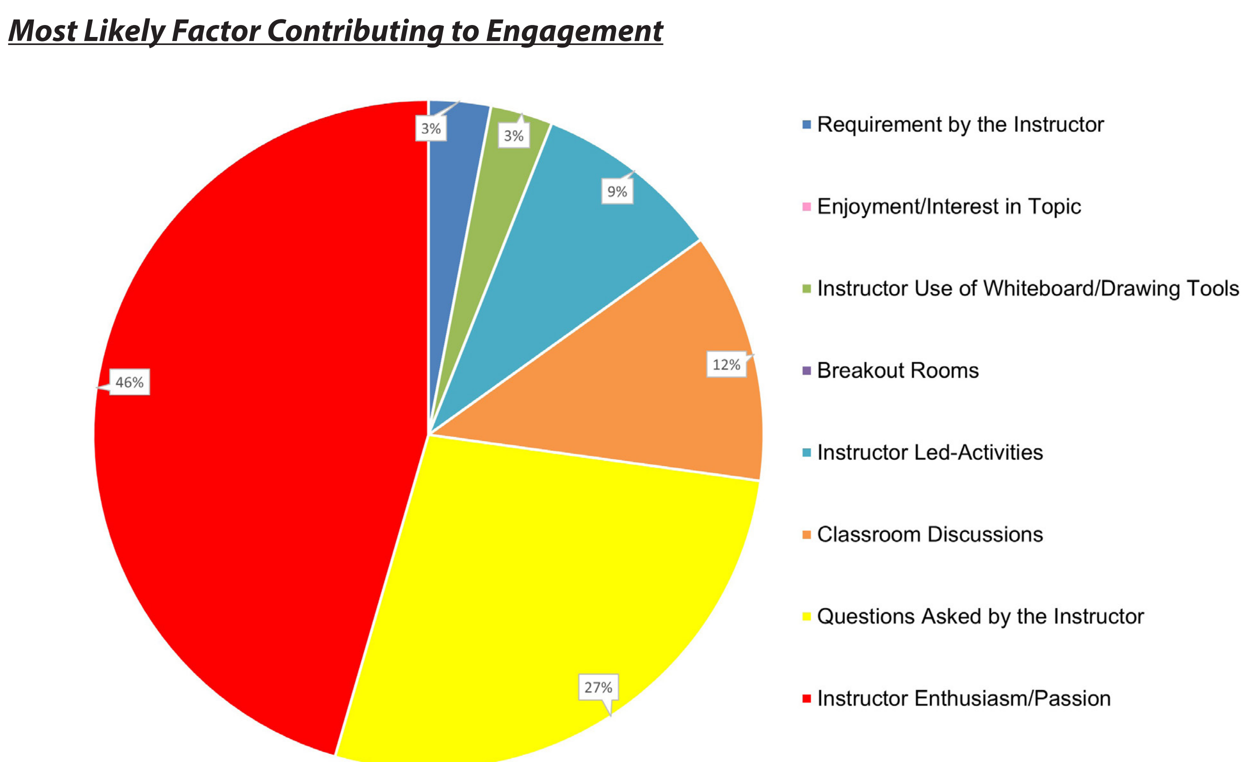

Figure 3*. Student survey of the greatest promotors of engagement in the remote undergraduate science classroom when compared to face-to-face classrooms. n=33*

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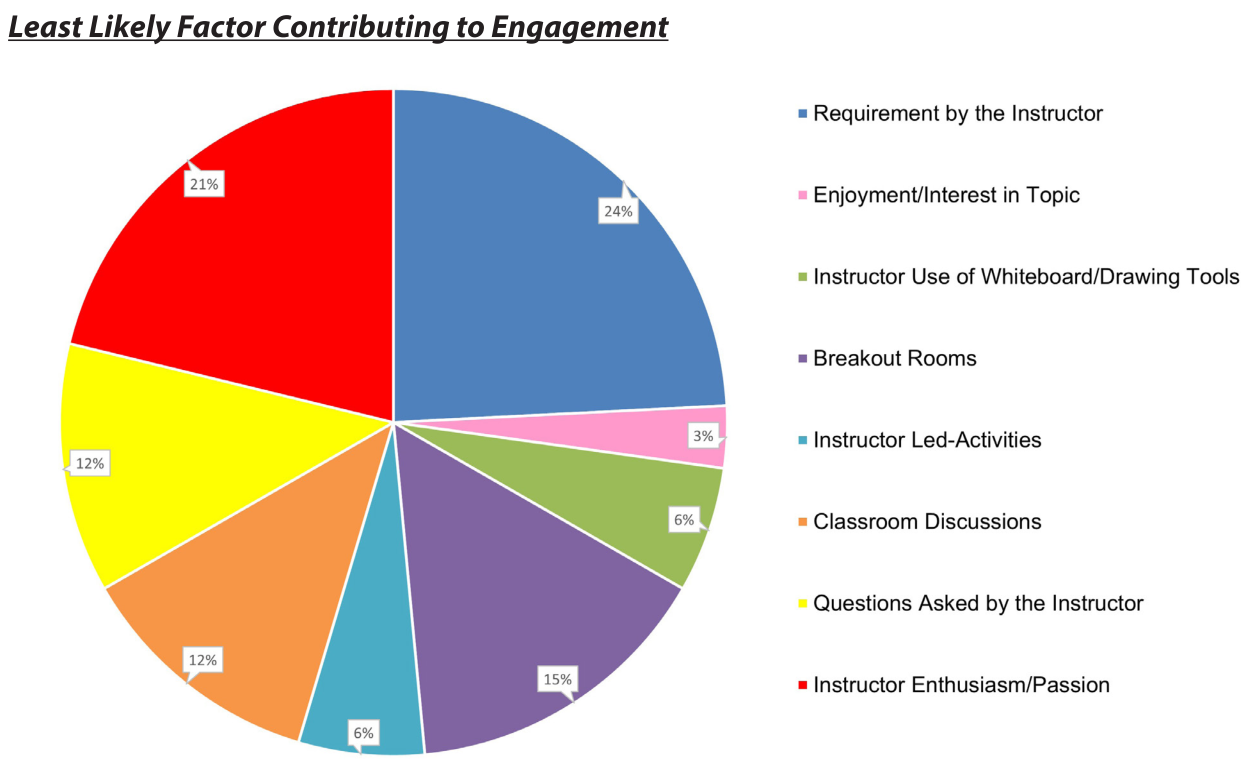

Figure 4*. Student survey of the factors least likely to increase engagement in the remote undergraduate science classroom when compared to face-to-face classrooms. n=33*

Basic Instructor Demographics

We surveyed the instructors of these undergraduate science courses to gain an understanding of their experience (Table 3). Forty-four percent of instructors had never taught an online course and 89% had never taught a hybrid course (n=9). Many of our courses were run hybrid in the sense that the lecture was held remotely while the lab was held in person at reduced capacity with social distancing. For this reason, we asked about the experience for both modalities. The majority of instructors had 6 years or more teaching experience (89%) (Table 3).

Experience in Remote/Online Teaching	Response (n)	Experience in Hybrid Teaching	Response (n)	Overall Teaching Experience	Response (n)
No	4	No	8	1-5 years	1
Yes	5	Yes	1	6-10 years	4
				11-15 years	2
				16+ years	2

Table 3*. Instructor survey demographics describing remote, hybrid, and overall teaching experience. n=9*

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Regarding the instructor perceptions of the remote classroom, there was no consistent response in the enjoyment of the modality as some seemed to enjoy the experience while others did not. Overall, instructors found it more difficult to connect with students (55%). They also reported that students either performed the same (44%) or worse (44%) in the remote classroom and engaged less in questions provided (67%) and group discussions (78%).

An open response question asked instructors if there were any factors that strongly contributed to or hindered their classroom management skills. While no common theme emerged, answers cited various issues such as their own unpredictable childcare and difficulty connecting with students. We also asked instructors if they felt students were able to achieve success in their science courses in the hybrid/remote learning environments in the same way they had in their own previous face-to-face courses. Again, no common themes emerged but response included that it may depended on their student's own motivation or independence as well as the type of assessment given. Other open response questions included instructors' recommendations on courses which would or would not work well remotely, what suggestions they have for improvement to remote science courses, and if they gained any additional skills during their time remote teaching. Overall, instructors felt that remote learning did not work well for laboratory courses and improvements could include additional preparation time, better training for the remote format, and soliciting students for their recommendations. While there was no major theme for skills gained during remote teaching, individuals reported increased proficiency with technology and active learning strategies.

Discussion

Undergraduate science courses are often taught in the face-to-face format, yet the COVID-19 pandemic forced most into a remote learning environment. In this study, we investigated the effects of remote learning on student engagement and perceived success in face-to-face undergraduate science courses from both the student and instructor perspectives. Science courses which are particularly challenging and considered gateway STEM courses were chosen for this study (undergraduate biology, chemistry, physics) (Freeman et al. 2011). Analysis revealed that students were less likely to engage by asking questions, responding to their instructor, or participate in group discussion in their remote science classroom when compared to their previous face-to-face classrooms. Despite the lack of engagement, many felt their success was about the same (44.4%). This warrants further research to investigate perceived success versus academic performance in the classroom and further delineating what

Survey Item	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Mean (±SD)
I enjoyed teaching a remote/hybrid.	1	3	1	3	1	3.0 (±1.3)
I found it more difficult to connect with students when compared to a traditional setting.	0	2	1	1	5	4.0 (±1.3)
Students engaged more in group discussion in the remote classroom.	6	1	0	2	0	1.8 (±1.3)
Students asked for more help in the remote classroom.	3	2	2	2	0	2.3 (±1.2)
Student performed stronger academically in the remote classroom.	1	3	4	0	1	2.7 (±1.1)
Students engaged more in the questions provided in the remote classroom.	4	2	0	3	0	2.2 (±1.4)

Table 4. *Instructor survey addressing perceptions on engagement and success in the remote undergraduate science classroom when compared to face-to-face classrooms. n=9*

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defines success from the student standpoint. In addition, further studies should investigate if course enjoyment plays a role in student success.

We investigated which factors were most impactful in contributing to decreased engagement and report that other distractions on the internet and stress, anxiety, and other mental health issues were the highest reported. While some students did not feel that mental health factors contributed to their disengagement, it's important to focus on the high number that did. In addition, an open response question addressing suggestions for improvement in the remote classroom recommended that instructors have a better understanding of the emotional concerns and strains of students. Considering instructors reported having a more difficult time connecting with students in the classroom, this is an area to highlight for future study. Future studies should explore this high-ranking contributing factor and investigate the implementation of support strategies to reduce this student concern. Perhaps surprising, class-standing and age of the students did not make a difference in the responses. It would seem likely that upperclassman, due to previous experience in college classrooms, would have been more likely to engage in group discussions, ask questions and feel more successful than underclassman, however, this was not true.

We also wanted to focus on what could improve student engagement in the remote classroom. We found the highest-ranking factors for engagement were instructor enthusiasm and questions asked by the instructor during class. The emphasis that remote students placed on instructor enthusiasm is interesting and suggests that students have some sort of emotional need or preferred personality type for their remote instructors. Their response indicates that enthusiastic individuals may fare better in remote teaching settings, yet this is likely a nuanced situation and further studies should investigate which specific "enthusiastic" behaviors in the remote classroom are leading promotors of engagement.

Students felt that the requirement by the instructor for students to engage was ineffective. The open response question which asked students for factors which would contribute to their success also revealed this common theme of increased engagement from the instructor. Students suggested increased instructor enthusiasm as well more engagement via the incorporation of group discussion, games, and other active learning strategies would support their success. Some responses noted that the remote learning format increased their workload and suggested that extended time on assessments would be beneficial.

From the instructor standpoint, they found it more difficult to connect with students in the remote classroom. They felt that students were less engaged in group discussion and classroom questions when compared to the face-to-face classroom. Overall themes from the instructors' open responses were that the depth of understanding was lacking in the remote classroom, as well as their own personal training in the format. They felt that students who would succeed in a face-to-face classroom would succeed in a remote classroom, but those who lacked motivation in a face-to-face classroom would fare even worse remotely. Instructors had mixed feelings on the enjoyment of teaching remote or hybrid courses. However, a common theme emerged from an open response question where instructors would not recommend a remote learning format for laboratory classes specifically. They felt these types of courses were important to keep face-to-face and did not translate well in the remote setting.

Overall, we found that undergraduate students were less likely to engage in the remote science classrooms when compared to face-to-face instruction, independent of class standing and age. Students felt that instructor enthusiasm was the major contributing factor for engagement in the remote classroom. Similarly, remote instructors felt that students engaged less in group discussion and found it harder to connect with students when compared to their face-to-face classrooms. While many undergraduate science courses have moved back into the face-to-face classroom space, we cannot ignore the increased demand for online learning, potential for future interruptions in face-to-face learning, and the declining undergraduate college course enrollment. While this study had limitations such as small sample size of both students and instructors, any information which can help instructors increase student engagement and success in the undergraduate science classroom is valuable.

About the Authors

Dr. Shannon Kispert is an assistant professor in the Department of Biological Sciences at Webster University. She primarily teaches undergraduate human anatomy and physiology. Carson Gross, BS, is a graduate of Webster University whose undergraduate research focused on pedagogy in the remote classroom.

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Health Sciences Student Perceptions and Attitudes Regarding Proctorio E-Proctoring Versus Testing Center

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Abstract

During the COVID-19 pandemic, academic institutions were forced to pivot toward online education. With the switch to online learning, e-proctoring became a popular choice to continue proctored exam assessments. Many concerns arose from this technology, including privacy, psychological, and performance concerns. With the resumption of in-person learning, faculty are faced with the question of continuing with e-proctoring alone, switching back to campus testing centers, or utilizing a combination of both modes. This study aims to understand health sciences students' perceptions and attitudes regarding e-proctoring versus testing center use. An 18-question survey was distributed to health sciences students. The survey had 244 respondents. Descriptive statistics and a one-sample t-test and Cohen's d were utilized to analyze the results. The results indicate that students feel less stress and anxiety using e-proctoring compared to testing centers. Participants also reported a perception of improved exam performance and good exam security. This research helps faculty and decision-makers understand student attitudes and perceptions regarding e-proctoring versus testing center use.
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Key words: e-proctoring, assessment, test anxiety, exam performance, online exams

Introduction

As a result of the COVID-19 pandemic, educational institutions were forced to re-evaluate how they assessed student performance since physical testing centers were often closed due to local precautions and policies (Harwell 2020). In a survey of faculty at four-year institutions, 29% responded that giving secure exams was one of their top three challenges during the pandemic (Fox et al. 2020). E-proctoring was an available tool to replace in-person testing centers and allowed faculty to continue to utilize proctored exam assessments. Online proctoring services grew heavily, with companies such as Proctorio seeing a significant increase in volume and revenue with the pandemic (Harwell 2020).

Many concerns arose regarding e-proctoring, such as assessment integrity, student performance, privacy, and psychological considerations (Kharbat and Abu Daabes 2021). Additionally, a study of medical students found concerns about the system wrongfully invalidating their exams, problems with background noise, and webcam issues (Meulmeester et al. 2021). A recent survey found that students were more anxious when taking an online proctored exam and that the heightened anxiety did not correlate with concerns about being flagged for cheating (Woldeab and Brothen 2021).

The impact of e-proctoring on student performance is another concern. A study of medical exams found that the method of testing, whether proctored online or on-site, did not influence exam results (Andreou et al. 2021). However, although the performance didn't change, examinees did report potential privacy issues and increased test anxiety (Andreou et al. 2021). Woldead and Brothen (2021) also reported that increases in anxiety did not impede performance.

A relationship may also exist between course enrollment and the use of e-proctoring. A prior study indicated that students felt that e-proctoring would influence their choice to sign up for a class that utilized that mode of proctoring (Milone et al. 2017). The relationship between enrollment and the type of proctoring used is an essential factor for faculty as they plan their return to campus-based courses. With students returning to campus and with open testing centers, the next decision was whether courses should return to the traditional model of utilizing testing centers only, continue using the e-proctoring services only, or employ a combination of modes where students can choose their preferred proctoring service.

This study aims to describe health sciences students' attitudes and perceptions regarding the use of e-proctoring versus on-site testing centers. The study was geared toward

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the factors that motivate students to utilize one mode of testing instead of the other, such as transportation, accessibility, stress, and anxiety. The overarching research theme concerned student attitudes and beliefs about e-proctoring versus testing centers. The primary research question was whether students preferred using e-proctoring or testing centers. Secondary research questions (SQ1-5) were also included to help assess student situations.

PQ: Do students prefer to use e-proctoring or testing centers?

SQ1: Does the use of e-proctoring software impact student enrollment?

SQ2: Do students feel cheating is easier with e-proctoring compared to a testing center?

SQ3: Do students feel that their performance improves or decreases using e-proctoring versus testing centers?

SQ4: Do students report increased stress and anxiety with e-proctoring versus testing centers?

SQ5: Do students face equipment and service barriers to participate in e-proctoring?

Methods

This project was approved by the institutional review board of Weber State University (# IRB-AY21-22-329), and informed consent was obtained from all participants. During the spring of 2022, a confidential online survey of 18 questions related to using e-proctoring services versus testing centers for students enrolled in health sciences courses was distributed for participation. Testing centers in this study are described as campus-based centers with computers for web-based assessment in a secure environment with check-in procedures, proctors, and video monitoring. In essence, the only variation in the exam was the location of proctoring: in a center or at a location of the student's choosing. The survey was conducted through Qualtrics XM (https://www.qualtrics.com). Participation was voluntary, and no identifiable information was obtained. Participant recruitment was mainly in undergraduate anatomy and physiology courses, although students in medical terminology and pathophysiology courses could also complete the survey. In total, 23 course sections, all at the 1000 or 2000 level, were included in the survey distribution. The survey was given between the midterm and final exams in the semester and did not influence course grading. Students did not receive extra credit for survey completion.

Exams within the courses surveyed consisted of multiple-choice questions only and were closed book. The allowed duration of all proctored exams was limited to two hours. However, most students completed the exams in an hour or less. The exams students took through e-proctoring or a campus testing center had the same web-based style with the same interface. The only difference was the proctoring service used by the students, either e-proctoring at a location of their choosing or a campus-based testing center.

Before taking the survey, students were provided with an informed consent page to give consent to participate in the study. For the survey, students compared on-site university testing center use versus Proctorio e-proctoring software, the e-proctoring service already selected for university use (http://www.proctorio.com). Bergmans et al. (2021) found that Proctorio was easy for students to use but had low sensitivity regarding cheating detection. However, students reported the perception that Proctorio prevents cheating (Bergmans et al. 2021). The questions in the survey covered various topics, including the preference for e-proctoring using Proctorio or testing center use, factors influencing their choice of mode, and exam integrity.

The survey was divided into two blocks. The first block (Table 1) consisted of 16 questions that linked to the primary and/or secondary research foci and utilized a five-point Likert scale with agreement options of "strongly agree" (5), "somewhat agree" (4), "neither agree nor disagree" (3), "somewhat disagree" (2), and "strongly disagree" (1). The final two questions (Table 3) allowed students to select any variable that applied to why they would choose to use a particular mode of proctoring. No questions were required on the survey, and participants were allowed to skip any question. Descriptive statistics of mean and standard deviation were utilized to present the results. A one-sample t-test was used to compare the mean of each result to a predetermined mean, which was three, corresponding to "neither agree or disagree" on the Likert scale. Cohen's d was also calculated for the effect size.

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Survey Question	Research Question
Q1: Taking an exam in Proctorio is less stressful than at a testing center.	SQ4
Q2: Taking an exam in Proctorio makes me less anxious than in a testing center.	SQ4
Q3: Taking an exam in Proctorio is more convenient than at a testing center.	PQ
Q4: Taking an exam in Proctorio enhances my performance compared to testing in a testing center.	SQ3
Q5: If I only had the option of taking exams in a testing center, my anxiety would have increased.	SQ4
Q6: If I only had the option of taking exams in a testing center, my performance would have increased.	SQ3
Q7: If I only had the option of taking exams at a testing center, I would have had difficulty with transportation to the testing facility.	SQ5
Q8: If I only had the option of taking exams through Proctorio, I would have to buy new technology, such as a computer, webcam, or microphone.	SQ5
Q9: If I only had the option of taking exams through Proctorio, I would have to purchase or upgrade internet service.	SQ5
Q10: Having the choice of testing in Proctorio or at a testing center enhanced my autonomy in the course.	PQ
Q11: If I only had the option of taking exams in a testing center, I would have withdrawn from the course.	SQ1
Q12: If I only had the option of taking exams through Proctorio, I would have withdrawn from the course.	SQ1
Q13: Students should only be given the option to use Proctorio OR a testing center, but not both.	PQ
Q14: It is easier for students to cheat when taking an exam using Proctorio than at a testing center.	SQ2
Q15: I prefer to take exams through Proctorio.	PQ
Q16: I prefer to take exams at a testing center.	PQ

Table 1. *Likert-scale survey questions and their corresponding research question.*

Results

The survey had 244 people consent to participate in the study. Of the 244 participants, 235 answered each question except one, as noted in Table 2 for question 15. The remaining nine participants consented to the study but did not answer any questions. Due to the relatedness of the 16 questions in the first block of the survey, the results should be considered as a whole rather than independent of one another. The statistical analysis of each Likert-scale survey question in the first block is listed in Table 2. The results of the second block, questions 17 and 18, are given in Table 3.

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Question	N	Mean	Std Deviation	t	Two-sided p	Cohen's d
Q1	235	4.20	1.16	15.881	<0.001	1.036
Q2	235	4.18	1.18	15.432	<0.001	1.007
Q3	235	4.76	0.74	36.545	<0.001	2.384
Q4	235	3.83	1.16	10.927	<0.001	0.713
Q5	235	4.15	1.23	14.365	<0.001	0.937
Q6	235	2.37	1.03	-9.333	<0.001	-0.609
Q7	235	3.03	1.48	0.265	0.792	0.017
Q8	235	1.44	0.90	-26.498	<0.001	-1.729
Q9	235	1.26	1.03	-21.338	<0.001	-1.392
Q10	235	4.30	0.91	21.899	<0.001	1.429
Q11	235	2.78	1.39	-8.006	<0.001	-0.522
Q12	235	1.41	0.82	-29.805	<0.001	-1.944
Q13	235	1.51	0.99	-23.058	<0.001	-1.504
Q14	235	1.94	1.21	-13.489	<0.001	-0.880
Q15	234	4.32	1.13	17.953	<0.001	1.174
Q16	235	2.03	1.21	-12.253	<0.001	-0.799

Table 2. *Statistical results for each Likert-scale survey question.*

Q1: Taking an exam in Proctorio is less stressful than at a testing center. (SQ4)

The average response was 4.20 (SD = 1.16) that students agree utilizing Proctorio is less stressful than taking their exams in a testing center. This result is statistically significant, t(234) = 15.881, p = <0.001. The frequency of answers showed 135 (57.45%) reporting that they strongly agreed, 52 (22.13%) somewhat agreed, 22 (9.36%) neither agreed nor disagreed, 13 (5.53%) somewhat disagreed, and 13 (5.53%) strongly disagreed with the statement.

Q2: Taking an exam in Proctorio makes me less anxious than in a testing center. (SQ4)

78% of students indicated that they either somewhat agreed or strongly agreed that they are less anxious using Proctorio and a testing center. The average opinion was 4.18 (SD = 1.18) with a significantly significant result, t(234) = 15.432, p = <0.001. Those reporting that they either somewhat disagreed or strongly disagreed made up 11.49% of the responses. Those that neither agreed nor disagreed made up 10.21%.

Q3: Taking an exam in Proctorio is more convenient than at a testing center. (PQ)

Students report a statistically significant opinion that Proctorio is more convenient than examinations at a testing center, t(234) = 36.545, p = <0.001. The average response was 4.76 (SD = 0.74). The frequency of answers showed 203 (86.38%) reporting that they strongly agreed, 19 (22.13%) somewhat agreed, 6 (2.55%) neither agreed nor disagreed, 2 (0.85%) somewhat disagreed, and 5 (2.13%) strongly disagreed with the statement.

Q4: Taking an exam in Proctorio enhances my performance compared to testing in a testing center. (SQ3)

The average response was 3.83 (SD = 1.16), with a statistically significant agreement that participants reported that using Proctorio enhanced their exam performance, t(234) = 10.927, p<0.001. The frequency of answers showed 90 (38.30%) reporting that they strongly agreed, 52 (22.13%) somewhat agreed, 67 (28.51%) neither agreed nor disagreed, 14 (5.96%) somewhat disagreed, and 12 (5.11%) strongly disagreed with the statement.

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Q5: If I only had the option of taking exams in a testing center, my anxiety would have increased. (SQ4)

Participants agreed with this statement, with an average response of 4.15 (SD = 1.23). The result was again statistically significant, t(234) = 14.365, p = <0.001. The frequency of answers showed 133 (56.60%) reporting that they strongly agreed, 53 (22.55%) somewhat agreed, 14 (5.96%) neither agreed nor disagreed, 21 (8.94%) somewhat disagreed, and 14 (5.96%) strongly disagreed with the statement.

Q6: If I only had the option of taking exams in a testing center, my performance would have increased. (SQ3)

Participants reported statistically significant disagreement with this statement, t(234) = -9.333, p = <0.001. The average response was 2.37 (SD = 1.03). The frequency of answers showed 7 (2.98%) reporting that they strongly agreed, 17 (7.23%) somewhat agreed, 91 (38.72%) neither agreed nor disagreed, 62 (26.38%) somewhat disagreed, and 58 (24.68%) strongly disagreed with the statement.

Q7: If I only had the option of taking exams at a testing center, I would have had difficulty with transportation to the testing facility (SQ5).

Participants had an average response of 3.03 (SD = 1.48), which is not statistically significant, t(234) = 0.265, p = 0.396. On average, students disagreed that transportation to a testing facility was a barrier to testing at a testing center. The frequency of answers showed 52 (22.13%) reporting that they strongly agreed, 46 (19.57%) somewhat agreed, 50 (21.28%) neither agreed nor disagreed, 30 (12.77%) somewhat disagreed, and 57 (24.26%) strongly disagreed with the statement.

Q8: If I only had the option of taking exams through Proctorio, I would have to buy new technology, such as a computer, webcam, or microphone. (SQ5)

The average response was 1.44 (SD = 0.9), which shows statically significant disagreement with the statement, t(234) = -26.498, p = <0.001. However, it is worth noting that 7% of respondents agreed somewhat or strongly with the statement. The remaining frequency of answers showed that 15 (6.38%) neither agreed nor disagreed, 25 (10.64%) somewhat disagreed, and 179 (76.17%) strongly disagreed with the statement.

Q9: If I only had the option of taking exams through Proctorio, I would have to purchase or upgrade internet service. (SQ5)

Only about 9% of participants responded in some form of agreement with this statement. The average response was 1.56 (SD = 1.03), indicating statistically significant disagreement with the statement, t(234) = -21.338, p = <0.001. The remaining frequency of answers showed 21 (8.94%) reporting that they neither agreed nor disagreed, 25 (10.64%) somewhat disagreed, and 169 (71.91%) strongly disagreed with the statement.

Q10: Having the choice of testing in Proctorio or at a testing center enhanced my autonomy in the course. (PQ)

Participants showed statistically significant agreement with the statement, t(234) = 21.899, p = <0.001. The average response was 4.30 (SD = 0.91). The frequency of answers showed 129 (54.89%) reporting that they strongly agreed, 58 (24.68%) somewhat agreed, 39 (16.60%) neither agreed nor disagreed, 7 (2.98%) somewhat disagreed, and 2 (0.85%) strongly disagreed with the statement.

Q11: If I only had the option of taking exams in a testing center, I would have withdrawn from the course. (SQ1)

Students reported statistically significant disagreement with this statement, t(234) = -8.006, p = <0.001. The average response was 2.28 (SD = 1.39). 20% of participants responded with some type of agreement with the statement. The remaining frequency of answers showed 50 (21.28%) reporting that they neither agreed nor disagreed, 32 (13.62%) somewhat disagreed, and 105 (44.68%) strongly disagreed with the statement.

Q12: If I only had the option of taking exams through Proctorio, I would have withdrawn from the course. (SQ1)

76% of respondents strongly disagreed with the statement posed in the question. The average response was 1.41 (SD = 0.82) with a statistically significant disagreement with the statement, t(234) = -29.805, p = >0.001. Only 2.5% indicated agreement of any kind with the statement. The remaining frequency of answers showed 26 (11.06%) reporting that they neither agreed nor disagreed and 24 (10.21%) somewhat disagreed with the statement.

Q13: Students should only be given the option to use Proctorio OR a testing center, but not both. (PQ)

An average response of 1.51 (SD = 0.99) indicated that respondents were in statistically significant disagreement with the statement, t(234) = -23.085, p = <0.001. The frequency of answers showed 8 (3.40%) reporting that they strongly agreed, 7 (2.98%) somewhat agreed, 17 (7.23%) neither agreed nor disagreed, 32 (13.62%) somewhat disagreed, and 171 (72.77%) strongly disagreed with the statement.

Q14: It is easier for students to cheat when taking an exam using Proctorio than at a testing center. (SQ2)

The average response was 1.94 (SD = 1.21). Participants disagreed with the statement at a statistically significant level, t(234) = -13.489, p = <0.001. The frequency of answers showed 10 (4.26%) reporting that they strongly agreed, 24 (10.21%) somewhat agreed, 32 (13.62%) neither agreed nor disagreed, 44 (18.72%) somewhat disagreed, and 125 (53.19%) strongly disagreed with the statement.

Q15: I prefer to take exams through Proctorio. (PQ)

The participants reported statistically significant agreement with this statement, t(233) = 17.953, p = <0.001. The average response was 4.32 (SD = 1.13). The frequency of answers

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showed 151 (64.53%) reporting that they strongly agreed, 42 (17.95%) somewhat agreed, 17 (7.26%) neither agreed nor disagreed, 13 (5.56%) somewhat disagreed, and 11 (4.70%) strongly disagreed with the statement.

Q16: I prefer to take exams at a testing center. (PQ)

The average response was 2.03 (SD = 1.21), indicating that students were in statistically significant disagreement with the statement, t(234) = -12.253, p = <0.001. The frequency of answers showed 14 (5.96%) reporting that they strongly agreed, 19 (8.09%) somewhat agreed, 35 (14.89%) neither agreed nor disagreed, 59 (25.11%) somewhat disagreed, and 108 (45.96%) strongly disagreed with the statement.

Q17: Which of the following are reasons why you would choose to use Proctorio for taking an exam instead of a testing center? (Select all that apply) (PQ, SQ1-5)

The responses most frequently chosen related to exam access with "convenience," "test any time of day (not limited to center hours)," and "easier to fit into schedule" being the options selected most often. The factors that were least often selected were to "avoid disease transmission (i.e., COVID-19)" and "family responsibilities." See Table 3 for full results.

Q18: Which of the following are reasons why you would choose to use a testing center for taking an exam instead of Proctorio? (Select all that apply) (PQ, SQ1-5)

Responses with the highest frequency were related to the home environment and the e-proctoring software. "Other people at home" and "pets at home" were reported as the most frequent reason to use a testing center. The most frequent response was "stress over "flagged" behaviors." "Privacy concerns" were also a concern when using the e-proctoring software and a reason to use a campus testing center. See Table 3 for full results.

Survey Question	Answers	Frequency	Percentage
Q17: Which of the following are reasons why you would choose to use Proctorio for taking an exam instead of a testing center? (Select all that apply)	Avoid disease transmission	92	5.31%
	Convenience	211	12.17%
	Easier to fit into schedule	218	12.57%
	Family responsibilities	104	6.00%
	More comfortable	169	9.75%
	More control of testing environment	134	7.76%
	No transportation needed	156	9.00%
	Test at any location	168	9.69%
	Test at any time of day	221	12.75%
	Test where you study	132	7.61%
	Use personal computer	129	7.44%
	Total Count	**1734**	**100%**
Q18: Which of the following are reasons why you would choose to use a testing center for taking an exam instead of Proctorio? (Select all that apply)	Don't want software on personal computer	27	4.43%
	Incompatibility of personal computer with software	20	3.28%
	Lack of personal internet	30	4.92%
	Lack of personal computer	12	1.97%
	Lack of webcam	17	2.79%
	Lack of microphone	12	1.97%
	Other people at home	129	21.15%
	Pets at home	74	12.13%
	Privacy concerns	47	7.70%
	Recording home environment	35	5.74%
	Stress over "flagged" behaviors	132	21.64%
	Testing center is a controlled environment	75	12.30%
	Total Count	**610**	**100%**

Table 3. *Frequencies of answers to open-ended survey questions.*

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Discussion

The survey results relay health sciences students' attitudes and perceptions about using Proctorio e-proctoring versus testing centers and provide a forum of discussion for course and campus decision-makers. Information about the primary and secondary research questions was gained and is presented in this section. In addition, the findings of this study will be compared with other findings for each question, as applicable.

PQ: Do students prefer to use e-proctoring or testing centers?

According to the survey results, health science students preferred using e-proctoring software for exams instead of campus-based testing centers. Although they did not have a direct comparison to testing centers, Meulmeester et al. (2021) reported that most of their respondents either approved or were neutral about using e-proctoring services for examinations. The current finding studies enhance that finding in that most students reported preferring to use e-proctoring compared to a campus testing center. Interestingly, a majority of students reported that both e-proctoring and campus testing center options should be available rather than requiring one or the other.

SQ1: Does the use of e-proctoring software impact student enrollment?

Regarding the first of the secondary research questions, the results show that students would still tend to enroll in classes if either e-proctoring or campus testing centers were used individually. Granted, the courses are required pre-requisite courses for many of our college's professional programs, which may skew their responses as most have to take the courses to meet their career aspirations. However, there is a concern that by limiting the proctoring services available to students, they may decide against enrollment.

SQ2: Do students feel cheating is easier with e-proctoring compared to a testing center?

Previous research has reported that Proctorio has not yielded promising cheating detection results (Bergmans et al. 2021). Yet, students reported at that time that Proctorio e-proctoring is a good tool for detecting cheating (Bergmans et al. 2021). Additionally, webcam-based proctoring was shown to deter cheating in an online testing environment (Hylton et al. 2016). The current survey results indicate that the majority of students (72%) feel e-proctoring does not provide enhanced cheating opportunities compared to testing centers. However, the results cannot be definitive, given that 14% of respondents thought it allowed for possible cheating.

SQ3: Do students feel that their performance improves or decreases using e-proctoring versus testing centers?

Regarding exam performance, the results show that students felt that taking exams in an online environment positively affected their performance compared to testing centers. Many studies have shown that students feel that their exam performance is hindered by e-proctoring, but their actual exam results did not agree with that assertion (Andreou et al. 2021; Kharbat and Abu Daabes 2021; Woldeab and Brothen 2021). These results contradict the findings of a few other studies that have shown a negative impact on scores (Hylton et al. 2016; Milone et al. 2017). The mixed nature of these results makes it difficult to conclude whether e-proctoring has a positive or negative effect on exam performance.

SQ4: Do students report increased stress and anxiety with e-proctoring versus testing centers?

The present survey results indicate that students at our campus did not follow the general theme that e-proctoring increases anxiety for exams. They reported that e-proctoring was their preferred examination method and was less stressful and anxiety-inducing than a testing center. Several studies have indicated the opposite effect – that students reported more anxiety or stress with e-proctoring (Elsalem et al. 2020; Meulmeester et al. 2021; Woldeab and Brothen 2021). However, students with more exposure to e-proctoring seem less likely to experience anxiety (Prakasha et al. 2021). The current study did not account for the past testing experiences of students with regard to e-proctoring. This is an area for further research consideration.

SQ5: Do students face equipment and service barriers to participate in e-proctoring?

Finally, there was a concern that only allowing students to utilize Proctorio may limit course accessibility due to barriers such as computers, webcams, and internet service. Although the survey results indicated that this was not a problem for most students, it is worth noting that 9% of the survey participants reported a barrier with equipment or internet access if they could not utilize campus testing centers. Given the correlation between socioeconomic status and academic achievement, it is crucial to consider these barriers when deciding what mode of proctoring a course will utilize (Broer et al. 2019). If both in-person testing centers and e-proctoring are available, students strongly agree that both should be made available to allow students to select their preferred mode.

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Conclusion

This study has provided insight into student attitudes and perceptions concerning e-proctoring versus testing center use. Health sciences students seem to prefer using e-proctoring services with reported perceived performance enhancement and decreased anxiety and stress. Future consideration should be given to confirm exam performance against actual exam scores and confirm preferences with student usage of e-proctoring versus campus testing centers.

About the Author

Justin Burr is an assistant professor of health sciences in the Dr. Ezekiel R. Dumke College of Health Professions at Weber State University. He teaches introductory anatomy and physiology, anatomy and physiology I and II, pathophysiology, and medical terminology.

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LGBTQIA+ Inclusive Teaching of Anatomy and Physiology

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Abstract

Anatomy and Physiology (A&P) is a foundational sequence of courses required for students to complete as a prerequisite prior to admission to a range of graduate health programs and degrees, some of which include medical schools, nursing, occupational and physical therapy, exercise science, cardiovascular technologist, diagnostic medical sonography, dental hygienist, respiratory care, and radiography. While undergraduate A&P course content is fairly standard, differences in curricula, as well as differences in the student populations within these classes exist. In this paper we examine ways in which a more inclusive teaching environment can be created to support an increased sense of belonging for LGBTQIA+ students within anatomy and physiology courses, potentially leading to higher retention and success rates (Fenaughty et al. 2019; Garvey et al. 2017; National Academy of Sciences 2017; Snapp et al. 2015). Inclusive teaching has largely been absent within STEM disciplines, leading to negative perceived classroom experiences within STEM courses (Snapp et al. 2015; Garvey and Rankin 2015). Faculty can help to reduce barriers to success faced by gender and sexual minority students by growing in cultural competency, using inclusive vocabulary, and infusing their courses with accurate content that allows all students to see themselves in the curriculum. https://doi.org/10.21692/haps.2023.001

Key words: DEI, Anatomy and Physiology, LGBTQ, Inclusive Education

Anatomy and Physiology: Who is in the Classroom?

Historically, diversity within higher education has been monitored in terms of male or female sex/gender, age, and race/ethnicity. Until recently, sex/gender data seldom captured representations of gender outside of the binary options of male and female (Garvey et al. 2015). For this reason, there is little data on gender diversity in STEM courses at the college level, and there is even less data on the representation of the spectrum of lesbian, gay, bisexual, transgender, queer, intersex, asexual, and all other gender identities (LGBTQIA+; see Table 1 for a list of definitions) in anatomy & physiology (A&P) courses (Cech and Waidzunas 2011; Cooper and Brownell 2016). Current national data estimates 9.5% of United States youth ages 13-17 are part of the LGBTQIA+ community (Conron 2020). Moreover, while 7.1% of the United States adult population represent the LGBTQIA+ community, the largest portion of adults in the LGBTQIA+ community are Gen Zers (McShane 2022). Since the Gen Z generation represents 66.6% of adult post-secondary students, they comprise the largest proportion of students currently participating in college classes (Hanson and Checked 2022). Although few data are available, it is likely that similar proportions of students entering college A&P lecture and lab spaces, and conducting biomedical research belong to the LGBTQIA+ community.

Gender and sexual minority students have lower academic achievement, higher reported instances of victimization, and a reduced sense of belonging compared to other students (Fenaughty et al. 2019). The Trevor Project's (2021) annual survey of LGBTQIA+ youth ages 13-24 years old confirmed the low sense of belonging among gender and sexual minority youth. Forty-two percent of youth surveyed reported contemplating suicide over the last year, with higher rates of suicide contemplation among respondents belonging to historically marginalized groups. In addition, 94% of participants surveyed directly linked the current political climate to their poor mental health and 66% percent of respondents indicated that they live in a non-LGBTQIA+ affirming household (The Trevor Project 2021). These data suggest that gender and sexual minority students in our A&P courses not only face the challenges and rigor of demanding content-heavy college courses, but have additional challenges finding a sense of belonging at home

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and in the classroom. This is important, since having a sense of belonging is credited with increased student success and retention rates in higher education (National Academies of Sciences 2017; Martinez and Munsch 2019), and lack of sense of belonging may account for why LGBTQIA+ students in STEM majors are 8% less likely to stay in the major (Hughes 2018).

Bisexual: A person whose primary sexual and affectional orientation is toward people of the same and other genders, or toward people regardless of their gender.
Cisgender: a gender identity, or performance in a gender role, that society deems to match the person's assigned sex at birth.
Gay: A sexual and affectional orientation toward people of the same gender.
Gender: A social construct used to classify a person as a man, woman, or some other identity. Fundamentally different from the sex one is assigned at birth.
Gender Identity: A sense of one's self as trans, genderqueer, woman, man, or some other identity, which may or may not correspond with the sex and gender one is assigned at birth.
Heteronormativity: Attitudes and behaviors that incorrectly assume gender is binary, ignoring genders besides women and men, and that people should and will align with conventional expectations of society for gender identity, gender expression, and sexual and romantic attraction.
Heterosexuality: A sexual orientation in which a person feels physically and emotionally attracted to people of a gender other than their own.
Homosexual/Homosexuality: An outdated term to describe a sexual orientation in which a person feels physically and emotionally attracted to people of the same gender. Historically, it was a term used to pathologize gay and lesbian people.
Intersex: An umbrella term to describe a wide range of natural body variations that do not fit neatly into conventional definitions of male or female. Intersex variations may include, but are not limited to, variations in chromosome compositions, hormone concentrations, and external and internal characteristics.
Lesbian: Usually, a woman whose primary sexual and affectional orientation is toward people of the same gender.
LGBTQIA: Abbreviation for Lesbian, Gay, Bisexual, Transgender, Queer, Intersex and Asexual. An umbrella term that is often used to refer to the community as a whole.
Transgender: An adjective used most often as an umbrella term and frequently abbreviated to "trans." Identifying as transgender, or trans, means that one's internal knowledge of gender is different from conventional or cultural expectations based on the sex that person was assigned at birth.
Two Spirit: An umbrella term encompassing sexuality and gender in Indigenous Native American communities.

The definitions for these terms were taken as presented or slightly adapted from the following resource:
LGBTQIA Resource Center Glossary (http://lgbtqia.ucdavis.edu/educated/glossary.html)

Table 1. *LGBTQIA+ Terms and Definitions*

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Campus Climate

The college campus climate shapes students' academic experiences and achievements by creating a gateway for student interactions and involvement, identity awareness, and overall well-being (Garvey and Flint 2017). Both blatant instances of inequality directed towards a person or group of people, and more subtle "micro-inequities'' can negatively impact student learning (Hall 1982). Moreover, when inequities are not adequately addressed, they may impact both learning in the affected classroom and the student's success at an institution (Hirschy and Braxton 2004). While dedicated LGBTQIA+ resource centers and policies can help to create an inclusive campus climate, it is important to avoid promoting segmentation of the campus into safe spaces as a replacement for creating a campus-wide expectation of safe spaces and sense of belonging among students, faculty, and staff (Yost and Gilmore 2011). Moreover, research indicates that there is something more influential in creating an inclusive campus environment than an institution's policies, norms, and values. The college academic experience is defined by the classroom environment and faculty interactions with students correlate with perceptions by LGBTQIA+ students about campus climate and culture (Garvey and Flint 2017). In this way, the college classroom environment serves as an even greater litmus test for a campus's overall climate towards LGBTQIA+ students (Garvey and Rankin 2015). Quantitative data indicate that "the average classroom experience" of LGBTQIA+ students is not supportive (Garvey and Rankin 2015). It is within the classroom experience that sexual and gender minoritized students may feel "silenced or harassed" by their peers or even the faculty (Garvey and Rankin 2015). In one study, only 3% of students reported hearing negative, derogatory comments from faculty aimed at LGBTQIA+ students, but 57% of the students reported negative, harassing, and derogatory comments from their peers (Yost and Gilmore 2011). More recent studies suggest that LGBTQIA+ students experiencing or hearing negative comments about gender expression and sexuality continue to be within the 50 percentiles (Fenaughty et al. 2019).

Means by which faculty negatively influence the classroom environment and perceptions of campus climate include not welcoming lived experiences shared by LGBTQIA+ students, excluding LGBTQIA+-related topics within the course curriculum, singling out LGBTQIA+ students as a voice for the community in a practice known as tokenism, using homophobic and transphobic language, and using a student's possible sexuality or gender identity as a means of (incorrectly) predetermining academic aptitude (Garvey and Flint 2017; Fenaughty et al. 2019). These classroom-level experiences lead to withdrawal of LGBTQIA+ students from active participation within the course, lower academic achievement, and a negative perception of the campus climate, despite campus initiatives and policies that are aimed at building an inclusive and welcoming campus (Fenaughty et al. 2019; Garvey and Flint 2017).

Faculty can positively influence the classroom environment by taking steps to ensure all students, including LGBTQIA+ students, feel safe, valued, and respected. One way to do this is by creating a class where all students can see themselves within the course content and curriculum (Garvey et al. 2015). Sexual and gender minority students enrolled in courses that include LGBTQIA+ topics within the curriculum obtained higher GPAs, reported feeling safer, experienced fewer instances of victimization, and reported fewer reports of homophobic and discriminatory slurs compared to LGBTQIA+ students that do not experience LGBTQIA+-embed curriculum within college courses (Fenaughty et al. 2019; Snapp et al. 2015). Critically, while intentional inclusion of LGBTQIA+ topics, assignments, and other learning activities that are embedded throughout the curriculum may support a sense of belonging for sexual and gender minority students, how these topics are included is an important consideration, since further isolation of LGBTQIA+ students can occur when topics are presented as an "aside" or separate from the "normal" curriculum, enhancing the notion that being gay, lesbian, intersex, or gender-nonconforming is not "normal" (Snapp et al. 2015).

LGBTQIA+ Inclusive Teaching of Anatomy and Physiology

Inclusive teaching refers to any approach that addresses the needs of all students from diverse backgrounds (Abby et al. 2021). The following section outlines how we can engage in inclusive teaching of anatomy and physiology by recognizing stereotypes, addressing our own biases, creating an inclusive classroom climate through our interactions with students, and teaching course content that includes a variety of examples and perspectives. These inclusive teaching strategies will not only benefit LGBTQIA+ students in higher education but can create an inclusive learning environment in which all students are valued and able to succeed.

Recognizing Stereotypes and Addressing our own Biases

Central to creating an inclusive classroom and building faculty-student relationships that reduce barriers to success is recognizing implicit bias and acting with *cultural humility* (Garvey and Flint 2017). Smith and Foronda (2021) define cultural humility as "a lifelong process of exploration and reflection that fosters trust and relationships''. Cultural humility involves the constant, lifelong evaluation of beliefs and how those beliefs, often taught to us and not consciously acknowledged, impact a balance of power and perception of individuals and populations we encounter (Green-Moton and Minkler 2020). Part of this is having an awareness that we live

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in a society in which sexuality is typically assumed straight (heteronormative) and where gender is assumed to align with external genitalia and the sex assigned at birth (gender normative) (Chrobot-Mason et al. 2001; Kitzinger 2005; Bilimoria and Stewart 2009; Braun and Clarke 2009; Cooper and Brownell 2016). It is recognizing that the time when individuals become aware of and accept their LGBTQIA+ is unique to each person. Since the development of these identities often occurs in the period between puberty and young adulthood, this means recognizing that an individual's identity may change during their time in higher education (Kinnish et al. 2005; Morgan 2013; de Monteflores and Schultz 1978; Rust 1993; Calzo et al. 2011; Cooper and Brownell 2016; Vaccaro 2006). In reflecting on, and acknowledging biases it is important that faculty begin to abandon outdated academic belief systems that support a "color-blind" approach, which leads to an invalidation of the student's experiences, language, and culture that can provide valuable insight and deeper understanding of content in the context of societal intersectionality and cross-curricular application (Farrelly and Hernandez 2022). Guiding students through activities, discourse, and lessons to experience the uncomfortable messiness of the content that challenges their own biases and world views, while linking content to their current world, allows the student and faculty to share experiences, validate one another, grow in empathy, and become more culturally and socially aware. This is the essence of higher education, with new experiences and application of content the academic environment supports a growth-mindset classroom experience (Farrelly and Hernandez 2022).

Interactions with Students: The Inclusive Syllabus

Faculty influence the class environment through their interactions with students inside and outside the classroom (Ambrose et al. 2010). Since one of the first interactions students have with an instructor is through reading the syllabus, including a statement on your syllabus that affirms your commitment to values of inclusion, diversity, and equity can set the tone for the classroom environment. It explicitly demonstrates to students that you value and respect differences between individuals and articulates to your students your desired classroom climate. To write a diversity statement, we suggest that faculty consider who is in their classroom and should feel included, what they want to convey to students about their expectations of a classroom environment where differences are respected and valued, and how respecting differences may lead to positive learning outcomes (see Box 1 for examples of diversity statements).

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Diversity Statement

I will strive to ensure that all students are treated with respect in this class. I welcome diverse people of different ages, backgrounds, beliefs, ethnicities, social classes, genders, gender identities, gender expressions, national origins, documentation statuses, religious affiliations, sexual orientations and learning styles. I expect everyone in this class to work together to cultivate a respectful and inclusive environment for every other member of the class. If you experience disrespect or discrimination in this class, please report your experiences to me.

Statement on Pronouns and Preferred Names

I believe that everyone has the right to be addressed by the name and personal pronouns that correspond to their gender identity, including non-binary pronouns (they/them/theirs, ze/zir/zirs, etc). Students can update their pronouns in the learning management system user settings. If you have not yet updated your pronouns in the learning management system, you can do so at the beginning of the term so that I can make sure to refer to you by using the correct pronouns. I also recognize that preferred names and pronouns may change during the semester. If at any point during the quarter you would like to be addressed differently, please let me know.

As part of our commitment to inclusion in this course, it is important that all students in this class respect the preferred names and pronouns of their peers. Mistakes in addressing one another may happen. If you make a mistake or are corrected, please briefly apologize, and correct yourself. To learn more about personal pronouns and why they are important I recommend you visit the website: mypronouns.org.

The biology faculty agree to promote a culture of compassion in our classrooms, labs, and in our student organizations. We actively strive to know our students as individuals so that all students can be comfortable and confident to seek help if necessary. We may not share all your experiences, but we will listen and do everything we can to help you be successful.

To accomplish this:

- *If you have a set of pronouns or name(s) that are different from what appears in your official record, please let me know as soon as possible.*
- *If you feel like your performance is being impacted by experiences, whatever they may be, outside of the classroom please talk to me and use me as a resource. I am here to support your development in all aspects.*
- *As many are, I am still learning about diverse perspectives and identities and continue to seek new knowledge and perspectives. If I or anyone else in the class says something that makes you feel uncomfortable, please talk to me about it.*

Your experience in this classroom is extremely important to me. I strive to create a learning environment and classroom where you are treated with respect. I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, immigration status, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences.

At times, we may discuss difficult and complex topics and I welcome and value all perspective. All members of this class are expected to contribute to a respectful, welcoming, and inclusive environment for every other member of the class.

To accomplish this we will all embody the principles below:

- *We believe that all human bodies have value and deserve respect -* ***NOTHING*** internal or external changes this. We speak with respect about the bodies around us and in front of us - ***including our own***.
- *We understand that diversity and representation are vital to learning and our community.*
- *We use language that includes everyone.*
- *We know that sex and gender are not binary.*
- *We acknowledge that race is a social construct.*
- *We address people the way they would like to be addressed, including names and pronouns, and we do not make assumptions based on someone's appearance.*
- *If you have a preferred set of pronouns or name that is different from what appears in your official record, please let me know as soon as possible.*
- *We believe the lived experiences that others share with us.*

I hope to create a learning environment that supports a diverse body of students, diversity of thoughts, perspectives, and experience and that honors your identity. As many are, I am still learning about diverse perspectives and identities and continue to seek new knowledge and perspectives. If I or anyone else in the class says something that makes you feel uncomfortable, please talk to me about it.

If you feel like your performance is being impacted by experiences, whatever they may be, outside of the classroom please talk to me and use me as a resource. I am here to support your development in all aspects.

**Note: This statement represents contributions of multiple HAPS members and many listserv discussions.*

Box 1. *Examples of Diversity Statements for inclusion in course syllabi*

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Inclusive Language and Curriculum

Some topics covered within biology courses, including A&P, are unique to the discipline. In an attempt to not silo these topics, we acknowledge that topics surrounding inclusive language and curriculum also are important and relevant within a wide variety of courses and programs such as social science, public health and policy programs, art, history, and sex and gender studies courses. Ultimately, the ability to create an inclusive classroom hinges more on developing a classroom culture and environment, where all members feel comfortable to be themselves regardless of sex, gender, age, weight, race, or any other real or perceived difference. The setting of this culture depends on the instructors' ability to set the appropriate tone and create ground rules for acceptable interactions. This begins in the syllabus, as mentioned above, and must be carried throughout the course by consistently using accurate language to refer to all people, structures, and concepts.

Especially within the sciences, inclusion is the biologically accurate way to present diversity and variation throughout all levels of organizations. For example, the idea that variability in form and structure is inherent to the entire field of biology and is represented within a myriad of biological traits in most species (such as variation in pigmentation, weight, height, body shape, and form), and similarly, this diversity is present within all organs, including those used for reproduction. Incorporating gender inclusive language creates an environment where LGBTQIA+ students feel seen, safe, and included, and normalizes and raises the standards for using a language that acknowledges gender and sex as a gradient or continuum trait of humans.

We recognize that developing lectures and teaching materials that are engaging, relevant, and reflect our most current understanding in the field is time consuming and often feels like a tradeoff between teaching the essentials *versus* teaching the new. This task becomes more daunting as the semester progresses, grading piles increase, and available time for innovation becomes scarcer. Incorporating inclusive terminology, in an area that is quickly changing, with the fear of saying the wrong thing and possibly offending the students whom we are trying to include is no less daunting. However, it is possible to make your classroom more inclusive without overhauling your entire curriculum, switching textbooks, or even being fully proficient in our fast-changing understanding of LGBTQIA+ terminology. Small, consistent changes add up and can convey a sense of inclusion. Box 2 lists small changes one can make, from least time-consuming to most, that can create subtle, but noticeable modifications in your class culture. Work by Zemenick et al. (2022) and Cooper et al. (2020) provide more extensive explanations and examples to incorporate LGBTQIA+ students in the classroom.

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Least effort

More effort

1. **Incorporate DEI inclusive language in your syllabus.** This does not need to be specific for LGBTQIA+ students only. In fact, recognizing all students, regardless of their external appearance, ethnic, sex or gender identification is important, so as not to inadvertently exclude students that are not LGBTQIA+.

   Example: Provide your pronouns next to your name in your syllabus. Include a Diversity Statement within your syllabus (See Box 1 of samples)

2. **Acknowledge that you are learning the terminology and might make mistakes.** It is a great example for our students, who are forced to learn and use A&P terminology all the time, that their professors are also learning and can make mistakes. As long as you are willing to take risks and make mistakes, you represent the qualities that we try our students to develop; willingness for growth and courage to learn.

   Example: In this classroom, I will do my best to reflect our current understanding of this field and use terminology that reflects inclusion and respect for all people. However, I am still learning and might make mistakes. It is never my intent to offend, please let me know if I use a wrong term or say something that offends you.

3. **Remove gendered color coding and symbols from PowerPoints and handouts.**

   Example: Don't use pink/red to refer to females and blue for males. Choose colors and symbols that are not culturally associated with a particular gender like green and purple.

4. **Do not conflate sex with gender.** When referring to biological differences between the sexes, do not use terms women and men which refer to gender. Instead, use male and female which refer to sex.

   Example: Instead of saying "Women have smaller bone density and a greater risk of developing osteoporosis," say "Females have smaller bone density and a greater risk of developing osteoporosis."

5. **Focus on the mechanism that causes the purported sex difference.** The suggested modification in #3 above is a great start, but it does not include intersex individuals, or possibly individuals undergoing gender-affirming treatments. To make the above statement more inclusive, and more accurate, we can reframe the statement to reflect the causes of the described sex-difference. Typically, etiology of the difference is the hormone producing organ or the target tissue responding to the hormone. By rephrasing our statement to the organ, the focus switches from the individual sex to the biological/physiological mechanism driving the difference that may or may not been seen in all individuals and not isolated to one portion of the species.

   Example: Individuals with decreased estrogen levels or on androgen suppressing medication, have reduced bone density, putting them at an increased risk for osteoporosis.

Box 2. *Examples of changes that can be made to courses to increase inclusivity, arranged from least effort to more effort for implementation.*

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Creating an inclusive environment, while teaching scientifically accurate information, is essential for future healthcare workers, an important competence that has been recognized by the Liaison Committee on Medical Education and has been emphasized just recently by the Association of the American Medical Colleges (AAMC 2022). One such example of the need to present scientifically accurate information and its potential impact within the healthcare field is the role of sex hormones. Careful consideration to not portray sex hormones as gender-specific hormones that determine "masculine" or feminine" biased qualities but instead as non-gender specific, each having function and influence on the anatomy and physiology in all individuals (Hayssen 2020). In presenting sex hormone action in this manner, we accurately teach the function of these hormones, while correcting misconceptions leading to heteronormative falsehoods.

Table 2 lists topics taught in Anatomy and Physiology courses that can serve as gateway topics for the use of LGBTQIA+ inclusive terminology and topics. Many of these topics can also be taught in varying depth in other science courses. For example, topics that focus on sex differences can be addressed in almost any physiological system taught in A&P, and they can also be addressed in neuroscience and pathophysiology courses where sex hormones play important role in establishing and maintaining sex differences in the nervous system, and consequently modulate sex differences in behavior and neurodegenerative disease. Similarly, the topic of sexual differentiation can be addressed broadly in A&P. However, sexual differentiation can also be addressed in much more depth in courses such as genetics where it would be appropriate to discuss the effects of gene regulation on sex differentiation of the bipotential gonad and also in embryology where it is appropriate to focus on the many factors that regulate development of the reproductive system. Beyond the incorporation and use of inclusive terminology within A&P, Long et al. (2021) suggests that a gender-inclusive classroom environment includes five foundational practices: authenticity, continuity, affirmation, anti-oppression, and student agency. These five gender-inclusive practices are focused on scientific accuracy and depth over simplification, intentionality in creating a classroom expectation of inclusion, the acceptance of sexuality and gender diversity as normal and not something to be stigmatized, and the ability to speak to experiences while being encouraged to question and to make societal connections (Long et al. 2021).

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Topics appropriate to incorporate sex and gender inclusive language.	Unit in A&P	Other potential courses/teaching opportunities (Intersectionality/integration between courses)
Sexual differentiation	Reproductive systems	Embryology Genetics Developmental biology Endocrinology
Reproductive systems	Reproductive systems	Endocrinology Physiology
Sex differences and effects of sex hormones on physiological systems	Every system where sex steroids are involved: Skeletal systems Nervous systems Endocrine system and interspersed throughout skeletal and nervous systems Cardiovascular system Respiratory system Muscular system	Physiology Pathophysiology Exercise science Biology of aging Immunology
Sex differences in non-human animals	Not directly appropriate	Animal behavior/Ethology Behavioral endocrinology Comparative physiology/anatomy

Table 2. *Courses conducive to adoption of gender-inclusive language and topics*

Barriers to Inclusive Teaching

Factors that influence the inclusion of LGBTQIA+-related content into collegiate curriculum include, but not limited to, faculty being empowered and motivated to deliver curriculum inclusive of the student population (Garvey and Rankin 2015), faculty finding value in inclusive teaching practice and content incorporation, faculty status, and adjunct status, pay, and time commitment (Garvey and Rankin 2015). Geographical region can also influence the degree to which faculty are willing to include LGBTQIA+ topics and discussions within the curriculum. Areas that show a tendency toward more progressive ideologies exhibit a welcoming and more inclusive environment towards LGBTQIA+ students, leading students to indicate a more positive campus climate towards LGBTQIA+ students. In more rural areas or ideologically conservative regions of the country, LGBTQIA+ students report less tolerable learning environments and social climates that lead to fears of retaliation, hate crimes, isolation, and silence (Garvey and Flint 2017). Students within these regions rank campus climate towards LGBTQIA+ students lower. Adopting inclusive language in class content, especially in rural areas, can significantly improve student experience on a campus that might not be accepting of diverse student populations.

Conclusion and Future Considerations

The college classroom is not the only public sector that is changing. In a recent article, it has been reported that 27% of Americans know someone who is transgender and 45% of Americans understand human sexuality as a spectrum trait rather than a historical binary perspective (Long et al. 2021). As educators, understanding who our students are as members of a community and society and the experiences they bring into our classrooms can create a learning experience that will not only support sexual and gender minority students, but increase awareness and perception

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within all students about the LGBTQIA+ community. Developing and modifying A&P curriculum to emphasize the anatomy and the physiology outside of a heteronormative vocabulary is a small step in accurately depicting human function. Removing the stigmatizing and isolating language that reinforces a binary view of human biology as the normal condition can support LGBTQIA+ students feeling a greater sense of belonging, academic success, retention in STEM and allied health fields, and persistence within A&P courses. The biological story told in A&P will have lasting influence on our student's understanding of the human body as they transition into their academic and professional careers. It is a fascinating story, and one that deserves to be told accurately and inclusively.

Employing Long's (2021) recommendations of gender-inclusive practices for creating and sustaining an inclusive classroom, how we communicate the biological story of anatomy and physiology through our classroom teaching and engagement as well the educating and training of medical and health care professionals in patient care will be areas of interest for future publication.

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Lawrence (Larry) Young is an instructor of biology and anatomy and physiology at Florida Southern College in Lakeland, Florida. He teaches Anatomy & Physiology and has developed and taught courses in the biology of sexuality and gender. Within his courses, he is intentional about creating an inclusive classroom experience centered around the intersectionality of the course content and societal implications. He strives to enhance student-teacher relationships that reduce barriers for student success. Larry serves as Communication Committee chairperson for the Human Anatomy & Physiology Society (HAPS) and a member of the HAPS Diversity, Equity, and Inclusion (DEI) Committee.

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A Peer-Led Anatomy Dissection Experience for Second-Year Medical Students

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Abstract

In the fall of 2021, a cohort of second-year osteopathic medical students took part in a regional dissection experience led by their peers. During the students' first year of medical school, when they would have normally participated in anatomy dissections, they instead took part in a prosection-based gross anatomy course due to COVID restrictions. Many students requested the opportunity to learn dissection techniques, dissect regions of interest for specialties, and participate in this medical school "rite of passage" when COVID restrictions eased. This article describes the planning and implementation of a regional dissection program for 42 second-year medical students that occurred outside normal curricular hours at the West Virginia School of Osteopathic Medicine (WVSOM). This program was led by two second-year osteopathic medical students who had previously performed a full donor dissection as well as assisted in teaching at the college level. One of the main advantages of this program was the use of a limited number of donors compared to the large number of students who were able to participate in dissection in a meaningful way. A disadvantage was that each pair of students was only able to dissect one region of the body during their sessions. A quality improvement survey was conducted after the experience and 26% of participants provided feedback for potential future programs at WVSOM. Students reported enjoying the experience and becoming more comfortable using dissection instruments. This dissection program could be used as a template for an anatomy elective, a brief introduction to dissection, or a summer course. https://doi.org/10.21692/haps.2023.005

Key words: gross anatomy dissection, peer learning, elective, mini-dissection experience, cadaver dissection

Introduction

The COVID-19 pandemic drastically changed the way that medical schools presented curriculum to their students (Hilburg et al. 2020; Kaul et al. 2021). Similarly to what occurred at many other institutions (Iwanaga et al. 2021; Papa et al. 2022), human dissection was the one part of the curriculum that changed the most drastically for the class of 2024 at the West Virginia School of Osteopathic Medicine (WVSOM). Due to COVID restrictions, the class was not able to participate in traditional dissections as first-year medical students. Rather, they participated in a small group prosection-based course.

Once the campus community was able to receive vaccines, a number of students from the class of 2024, now in their second year, requested a dissection experience. Many of them mentioned specific areas they would like to dissect, due to interests in specialties such as orthopedics and cardiology. This presented a challenge because most of the anatomy laboratory space is devoted to the first-year anatomy curriculum. The officers of the Atlas Club, the WVSOM anatomy club devoted largely to creating mock-practical exams for first year students, took on this challenge. Collectively, it was felt that providing a dissection experience for these second-year medical students who were willing to take time above and beyond their normal curricular hours to learn anatomy, was a worthwhile endeavor. One study reported that medical students feel that the time-intense aspect of dissection is a barrier to their participation in the practice (Whelan et al. 2018). Having a group of students willing to dedicate what little time they had to this experience showed how important it was to them. Another study highlighted the importance of dissection specifically for anatomical medical specialties (Wisco et al. 2015). Like our students, these students also requested specific regions for dissection based on specialty interest. Human dissection is an irreplaceable opportunity that is vital to many aspects of medical education and is crucial to these students' professional development (Ghosh 2017).

Most dissection-based anatomy education programs had to resort to virtual or prosection-based courses during the beginning of the pandemic. It remains unclear how this will affect anatomy knowledge retention, spatial awareness, and practical skills in this student population. Studies have shown

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participation in dissection is beneficial to many aspects of professional training. The most immediate benefit, of course, is that students have enhanced performance on anatomy-based knowledge assessments (Whelan et al. 2018). However, there are many other advantages to anatomical dissection (Ghosh 2017), including understanding complex spatial relationships, active involvement in learning, understanding morphological variation, building communication skills, and dealing with the stress of the medical world surrounding death and dying (Robbins et al. 2009; Singh and Kharb 2013; Willan and Humperson 1999). The body donor can be viewed as teacher and/or first patient who furthers the emotional development of students by teaching them respect and empathy (Bohl et al. 2011).

Ultimately, an opportunity for 42 second-year medical students to participate in human dissection was created. The purpose of this article is to describe how this regional dissection program was planned and implemented. This type of dissection experience may lend itself as a model for anatomy courses with large enrollments combined with limited time, space, and donors. This article will highlight challenges that were encountered during the planning and working sessions, as well as how they were circumvented. It will also discuss the benefits and shortcomings of the program for the second-year WVSOM students who participated, some of whom volunteered their feedback when the program concluded.

Methods/Program Description

The four authors of this article include the two medical student peer leaders and the two anatomy faculty advisors for the project. The logistics of this regional dissection program relied heavily on the number of students who wished to participate outside of normal medical school curricular hours. To determine participation, interest was gauged via email from the WVSOM class of 2024, a total of 197 students. Approximately 50 students expressed interest in taking part in the experience. Based on this number, a proposal was put together for approval through the WVSOM Human Gift Registry to secure donors and laboratory space. Four donors were dedicated to this project and were housed in the anatomy lab along with the donors being dissected by the first-year class (class of 2025). The decision to have only four donors for this project was based on a space limitation within the anatomy lab. Once our program was complete, these four donors were then used for prosections for the first-year class in the spring of 2022 so that students could continue to learn from them.

Once institutional approval was completed through both the WVSOM Human Gift Registry and Student Life Office, a schedule and syllabus were compiled, as required for student organization educational events. Students were divided into groups in accordance with WVSOM COVID protocols. Students were assigned to the four donors, with 12 to 13 students working on each, but only 4 to 6 students present at the table during any given dissection session. Two or three students were assigned to one of the following regions of the body that they would be working on until completion: upper extremity, lower extremity, head/neck, abdomen/pelvis, or thorax (Table 1). Each team had a total of 4 dissection sessions, each lasting 2 hours (Table 2). To follow an example, if you were on Team 1 assigned to the upper limb on donor number 1, you would have attended sessions 2, 4, 6, and 8. Each session ran for 2 hours in the evening after academic obligations. Students were welcome to come into the lab on their own time if dissections were not completed within a given session.

Region	Donor 1	Donor 2	Donor 3	Donor 4
Upper Limb	Team 1 (3)	Team 2 (2)	Team 3 (3)	Team 4 (3)
Lower Limb	Team 5 (2)	Team 6 (2)	Team 7 (2)	Team 8 (2)
Thorax	Team 9 (2)	Team 10 (2)	Team 9 (2)	Team 10 (2)
Abdomen	Team 11 (2)	Team 12 (2)	Team 13 (2)	Team 14 (2)
Head and Neck	Team 15 (2)	Team 16 (2)	Team 17 (2)	Team 18 (2)

Table 1. *Team assignments (number of student participants in parentheses). Each team completed four dissections in the indicated region.*

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	Upper Limb	Lower Limb	Thorax	Abdomen	Head & Neck
Dissection 1	back ***Session 2***	gluteal region and posterior thigh ***Session 2***	skin thorax, muscle identification ***Session 1***	abdominal muscles ***Session 1***	Skin neck ***Session 3***
Dissection 2	arm and axilla ***Session 4***	anterior thigh ***Session 4***	rib cage removal & heart ***Session 3***	celiac trunk ***Session 3***	triangles of the neck ***Session 4***
Dissection 3	brachial plexus and forearm skinning ***Session 6***	anterior and posterior leg ***Session 6***	posterior thoracic wall ***Session 5***	superior/ inferior mesenteric arteries ***Session 5***	face and eye ***Session 5***
Dissection 4	forearm and hand ***Session 8***	foot ***Session 8***	clean up dissection & review ***Session 6***	posterior abdominal wall ***Session 7***	brain removal ***Session 7***

Table 2. *Each regionally assigned team participated in 4 sessions covering the indicated material.*

Prior to the start of the first session, the participants were emailed a presentation that is normally given to first-year students on their first day in the anatomy laboratory, modified based on the activities specific to this dissection experience. The presentation included the location of supplies within the laboratory, proper scalpel blade disposal technique, tissue removal, storage locations, workstation cleaning, and proper donor care. One staff member was present in the lab during the first few sessions to be sure that students knew the procedures and had all the necessary tools and equipment. The two peer leaders were present during all sessions to answer questions, guide dissections, and help with any student needs. Students also had access to the laboratory handouts used in the WVSOM curriculum for each region of dissection, referencing Grant's Dissector (Detton 2021). Many different anatomy atlases, including Grant's Dissector, were available in the lab.

Peer instructors began each laboratory session by briefly reviewing what each group was going to dissect that day with any helpful tips. Once each group started, the peer instructors would rotate from table-to-table teaching dissection techniques, answering questions about structures, and discussing clinical correlations. Since the students were well into their second year of pre-clinical curriculum, all the anatomy content was review and they were able to relate the dissection to previously studied material.

To determine the success of the regional dissection experience and any changes that would need to be made if a similar program were to take place in the future, a survey (Table 3 and 4) was sent out to the students who participated. As a Quality Assurance/Quality Improvement Project, it did not meet the regulatory definition of research and did not require IRB review. The survey consisted of 20 questions in total: 13 of the questions asked the students to rank different aspects of their experience on a strongly agree to strongly disagree Likert scale. There were two questions about their previous level of anatomy experience and 5 open-ended response questions.

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Survey Question	Mean Response (± SD)
1. My time dissecting helped me understand the anatomy of my assigned region in greater detail.	4.6 ± 0.5
2. This experience helped me make clinical connections in the body region I dissected.	4.5 ± 0.9
3. I felt more comfortable using dissection tools after participating in the dissection.	4.9 ± 0.3
4. I gained a better three-dimensional perspective of structures.	4.6 ± 0.9
5. I gained a stronger appreciation for human body donation.	4.7 ± 0.6
6. I gained a stronger appreciation for anatomical variations.	4.5 ± 1.0
7. I enjoyed the dissection experience.	4.8 ± 0.4
8. This experience made me consider alternative specialties.	3.2 ± 0.9
9. This experience was a waste of my time.	1.2 ± 0.4
10. This experience aided in my understanding of how structure and function are related.	4.2 ± 1.0
11. The WVSOM anatomy facilities provided a favorable learning environment.	4.6 ± 0.7
12. Peer learning enhanced my understanding during dissection.	4.7 ± 0.6
13. The time commitment was not a burden on my schedule.	4.1 ± 0.5

Table 3. *Mean level of agreement (± SD) to Likert-based survey questions answered by students after they had completed the regional dissection experience. (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree. (n=11).*

Open-Ended Survey Question	Summarized Responses
How did your time in lab aid in your integration of anatomy with other disciplines?	• structure and function • special relationships, • delicate touch for some surgeries
How did it aid in your clinical understanding of anatomy?	• consequences of pathology in certain regions/ structures • anatomical variation
What did you like most about this dissection experience?	• working with a team • testing each other's knowledge • practice with tools (ex. Scalpel) • deepening anatomy knowledge • seeing variation • fun and relaxed atmosphere
What did you not like about this dissection experience?	• too many people around the donor • not enough tools for everyone to work • not enough instruction
How should we improve the program?	• more time in the lab • offer more regions to dissect

Table 4. *Summarized student responses (key phrases) to open-ended survey questions soliciting feedback for program improvement.*

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Survey Results

Of the 42 students who participated in the regional dissection experience, 11 (26.2%) participated in the follow-up quality improvement survey for the program. The Likert scale survey questions, average responses and standard deviation can be found in Table 3. Only two of the 11 had participated in a human dissection course prior to this experience. The free response questions are outlined in Table 4 along with a summary of student responses.

The benefit cited most highly by the students was feeling more comfortable using dissection tools after the experience (Table 3). They also strongly agreed that peer learning enhanced their understanding during dissection, and they gained a stronger appreciation for human body donation, despite having participated in a prosection course and learning from donors the previous year. The students had a neutral response to the dissection experience stimulating them to consider alternate specialties, and all students that responded to the survey disagreed that the experience was a waste of their time.

Discussion

Overall, the second-year regional dissection experience was a positive experience for most of the students involved. Peer instructors observed that students enjoyed themselves without the pressures of being graded on the material. Students were free to explore the variability of human anatomical structures. In the post-experience survey, second-year WVSOM students strongly agreed that they understood the anatomy of their assigned region in more detail, made clinical correlations, felt more comfortable with dissection tools, gained a better 3-D understanding, and acquired a stronger appreciation for human body donation and anatomical variation. These results are similar to the results of other student feedback surveys following voluntary dissection experiences (Larkin and McAndrew 2013). It is recognized that students who chose to participate in the follow up survey may have felt the strongest about the experience, but the authors feel that the results provide validation for the program, nonetheless. By the end of the regional dissection program, peer leaders noted that the students were more confident and needed less and less instruction, as is often noted in a full dissection course.

Challenges

Some minor challenges were encountered while implementing the program. Trying to schedule the sessions around all the other campus events, exams, first year open labs, and mock practical exams, was the first major hurdle. Additionally, students are often part of a number of clubs. The schedule was created to not interfere with any of them for maximum attendance.

Logistically there were a few issues with students not showing up for the session without notification. This led to an uneven workload distribution when working in pairs. Peer leaders did their best to modify groups in the moment, for example moving someone from a group of three to fill in the gap. Since students were not graded on these activities, there was little incentive to attend other than the student's own desire to learn. One or two students generally missed each session out of the 16 to 24 expected students. Only two students dropped from the program. One student dropped out the day before sessions began and the slot was filled with a student who was previously undecided about participating. Another student did not attend any of the sessions and was unresponsive to email requests. One potential benefit of having no graded assignments was that students may have been more willing to fill in where needed and shift regions for a dissection day.

The two peer leaders found it difficult to have three groups at a table, dissecting different regions all at once. At times, there were 12 teams dissecting simultaneously, making it difficult to rotate through them quickly enough during a two-hour session. During the de-brief, the idea to have all the teams assigned to one region begin in the lab with slightly staggered start times was discussed. This would enable a slightly longer introduction to the day's goals for that group and ease some of the early questions. In the future, recruiting additional peer-leaders to facilitate during each session would help with this burden.

Skin, fat, and fascia removal always poses a challenge for new dissectors. It was especially challenging for students starting on certain regions such as the neck or gluteal region and required more hands-on time by the peer leaders. Teaching often revolved around the mechanics of dissection, and, again, having more instructors would be valuable to make the most use of lab time. Additionally, with a limited number of donors, there were issues of certain pathologies preventing full dissections of desired regions. Peer leaders often had groups visit other tables to share findings when a group was unable to see structures on their own donor. Since there was no accompanying didactic content, the students had to rely more on each other to remember and discuss pertinent material.

To not overburden the students, each person attended only eight total hours of dissection. For certain regions, such as head and neck, this was a relatively short dissection period. Time was a difficult balance that should be closely evaluated for this type of regional dissection program, as many groups may feel they are at a disadvantage, especially if there are grades involved. It was not crucial that everything be dissected to absolute completion, and often the dissections were not done bilaterally. This later allowed for the donors to be used as prosections for the first-year dissection labs.

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Benefits

Forty-two students, many of whom had never had the opportunity to work with a donor, were able to learn dissection techniques and review anatomy through this program. In the survey results, all of the students disagreed that it was a waste of their time. Peer leaders reported a very positive working environment during the sessions, observing strong teamwork and self-directed learning among the participants. Students seemed to have a particularly good disposition, as observed by the peer leaders, perhaps because this was a rare ungraded, pressure-free activity. Peer leaders enjoyed the experience of helping their peers in this relaxed environment. The timing of the program was also nice because it allowed students to refresh their anatomy with a hands-on activity before beginning their dedicated board study time.

From a faculty perspective, it is felt that this relatively short dissection program still achieved some of the same desired outcomes as the full dissection experience, such as peer-learning, problem solving, and discussion of clinical correlations in conjunction with the anatomy. The students gained confidence in their skills, which seemed to be particularly important for those wanting to pursue specialties in their area of dissection. While the donor may not have been these students' 'first patient', it was certainly impactful. The survey participants reported a stronger appreciation for human body donation, three-dimensional perspectives, and anatomical variation. This shows growth of both empathy and comfort when it comes to maneuvering the human body through dissection.

Peer-learning

This dissection experience was student led from the start, by two dedicated second-year medical students instructing their own cohort. These student doctors were in charge of the entire educational aspect of the experience and most of the logistics. Peer-assisted dissection has been shown to encourage active participation in dissection and even help students achieve higher academic scores (Han et al. 2015). Other institutions have adopted some form of near-peer learning, which may be closer to this experience since the student instructors had prior dissection experience. Near-peer learning has been shown to be beneficial to the students because the peer tutors can communicate with the student learners more effectively, and beneficial for instructor development both in learning anatomy at a deeper level, as well as honing teaching skills (Evans and Cuffe 2009). As previously reported by others, both peer leaders felt that it helped prepared them as they approached their own board exams, and our survey participants reported that peer learning enhanced their understanding during dissection (Han et al. 2015). Even in a larger class, it may be worthwhile to identify students with prior anatomy and dissection experience and disperse them evenly throughout dissection groups.

Concluding Remarks

Our regional dissection program filled a curricular and experiential gap for second-year students post COVID-19 restrictions. This regional dissection series can serve as a template for any time-limited or resource-limited anatomy dissection program, including a short-course, boot camp, elective, or summer experience. Only four donors were dissected by a total of 42 students over the course of eight total sessions, making good use of the time and resources available via overlapping team dissections.

Supplemental learning opportunities could easily be added. For example, students could present their regional dissection and some associated clinical correlations to other dissection groups. This could also be developed into a service-learning program where medical students teach visiting students from other educational programs and are assessed on their presentation skills and reflection of their involvement.
Both of our peer-leaders had prior dissection and teaching experience. However, if the program were to be run with new educators, we would suggest a brief teaching orientation focusing on how to guide new dissectors and encourage collaboration among the participants. Overall, this program was extremely successful and based on the survey, there were many positive outcomes for the participants.

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“Worst Thief Ever”- The Use of a Storyline to Engage Students in a Traditional Hands-on Lab Experience

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Abstract

A traditional anatomy lab using microscope slides to examine the structures of the integumentary system was enhanced to increase connections to the real world, student engagement, and interest in the topic by adding a forensic storyline where students examined structures of the integument in order to “solve the crime”. Student perceptions regarding the addition of the storyline to the lab found that 88% of students reported that the storyline increased the connections they made between the lab and the real world. Eighty-six percent of students stated that the storyline increased their interest in the lab and 83% said that it made them more engaged in the lab. Sixty-three percent of students felt that the storyline helped them to learn the material better. A five-step strategy guided the conversion of a typical hands-on anatomy lab exercise into an engaging experience based on a storyline using materials commonly found in the lab. This strategy serves as a template to transform lab exercises into experiences that use both a storyline and a hands-on activity as drivers of student learning.
https://doi.org/10.21692/haps.2023.007

Key words: storyline, hands-on learning, integumentary system, anatomy laboratory

Introduction

The laboratory is an important part of a Human Anatomy and Physiology course. The lab offers opportunities to manipulate materials and observe real life examples of anatomy (Dennis and Creamer 2022; Steger et al. 2020). Labs are usually divided by topic, such as the muscular system or cardiac physiology. Background information is often provided at the beginning of a session or as a pre-lab assignment while the in-lab activity focuses on materials such as microscope slides or dissections that students work with and observe. An example of a topic commonly taught in the anatomy lab is the integumentary system. Typical learning objectives for this lab may include: 1) label the layers of skin, 2) explain the function and importance of the skin layers (dermis and epidermis), 3) label and discuss the anatomy of hair and nails, as well as understanding skin pathologies or injuries such as burns, etc. A characteristic way to meet these objectives is microscopic examination of slides of skin, hair and nails. However, often students use the microscope activity as a list of requirements that must be “checked-off” before they can leave, rather than an exercise in critical thinking and understanding of a topic. Simply doing a lab exercise does not necessarily translate into learning from it (Hodges 2020).

Student activity does not always equate to student learning. Creating classroom environments that motivate students to learn about a topic and to think critically is a goal of most anatomy educators (Freeman et al. 2014; National Research Council 2012). Examples from the literature of strategies designed to meet this goal include using real-world situations and problems to promote motivation to learn and interest in a topic; these are major tenants of both context-based learning and project-based learning where information is presented within a knowledge framework rather than as detached facts (Condliffe 2017; Sevian et al. 2018). Setting the stage for learning with basic background information is crucial to learning anatomy as there are some concepts that students must know before they move to higher order thinking skills. Using appropriate disciplinary tasks to help students build knowledge is an important part of solving problems and applying anatomy to real-world situations (Dunbar 1995; Furtuck and Penuel 2019). However, producing experiences that build basic content knowledge, engage and motivate students and allow students to work together to solve problems can be daunting.

Project-based learning (PBL) strategies help students meet their learning goals. One factor common to good PBL lessons is the presence of a cohesive storyline that helps students make sense of the phenomenon (Nordine et al. 2019; Penuel et al. 2022; Reiser et al. 2021). The storyline drives the context of the content and supports social interactions among students as well as making anatomy content meaningful (Miller and Krajcik 2019). The storyline also provides motivation to learn (Reisener et al. 2021). While the literature reports several variations of using a storyline to promote engagement (Isabelle 2007; Penuel et al, 2022; Roth et al.

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2011), most reports focus on the storyline as the sole driver of student engagement.

Hands-on learning is another pedagogy associated with active learning that drives student engagement and can produce gains in comprehension. Hands-on activities, or "practice-base" exercises can increase knowledge retention and problem-solving skills (Ford 2015; Oseuntuyi 2021). Students prefer hands-on learning in the anatomy lab over exercises that do not involve the manipulation of materials (McDaniel and Daday 2017). The benefits of active learning, such as hands-on labs, are well established but it is common for college anatomy students to work through hands-on labs without thinking about what they are doing (Freeman et al. 2014).

A different approach to the construction of lab exercises is to use multiple drivers of student engagement instead of relying solely on hands-on activities or problem-based learning. This paper describes a simple way to add a storyline to a traditional hands-on anatomy lab to provide interest and context while maintaining the learning objectives and activities of the lab. The combination of a storyline with a hands-on lab peaks student interest, fosters collaboration and garners the benefits of hands-on learning. The hands-on storyline example lab presented in this paper is an approach to teaching concepts of the integumentary system (Appendix 1).

The storyline focuses on the theft of a painting from a local art gallery where the "worst thief ever" left all kinds of evidence from his/her integumentary system. Students must study the parts of the integumentary system to "solve the case"! They learn basic anatomy while working with reference slides and then compare slides containing evidence from the crime scene to make deductions about the identity of the thief. Students make connections between microscopic anatomy and human phenotypes such as melanin production in skin pigmentation, tattoo ink in the dermis, epidermal ridges on fingerprints, and the structure of hair as it relates to texture and color. While this lab emphasizes the integumentary system, the basic premise of this approach is not limited to this concept and could be used to teach other topics in anatomy and physiology. The development of a lab within this framework does not reinvent the wheel but enriches lab experiences that have been used successfully in the past by adding context through a storyline.

Methods

Design of the hands-on storyline Integumentary Lab

Modifying a traditional lab to include an engaging storyline involves five steps (Figure 1 and Appendix 2). The first steps are to identify the goals of the lab, determine how these goals are usually met in the traditional lab, and to procure the materials that are commonly used for the lab. The fourth step is to analyze how the materials used to meet the lab goals can be worked into the storyline as pieces of evidence and the final step is to modify the storyline provided in this paper to fit the evidence and make the storyline interesting for your students.

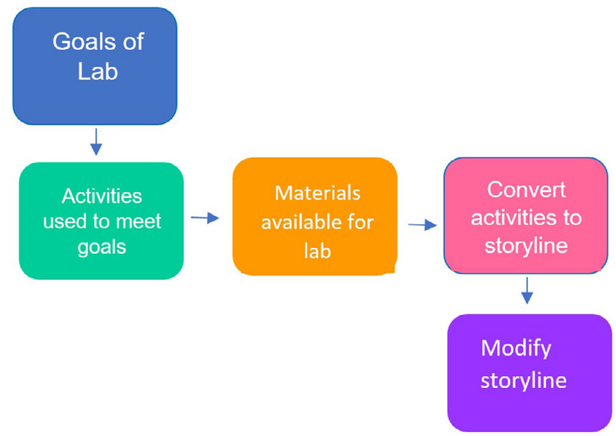

Figure 1. *Steps for adapting a hands-on lab to a storyline format.*

The example hands-on storyline lab for the integumentary system presented in this paper (Appendix 1) was built using materials commonly present in the lab, produced by the instructor, or purchased from a vendor. The template in Appendix 2 outlines the method to develop a hands-on storyline lab using common items in the lab. Effective active learning strategies start with a set of well-defined learning objectives (Barkley et al. 2014). These goals should guide instruction and serve as the basis for assessment. What follows is the list of learning goals set for this activity by the author.

By the end of this laboratory exercise students will be able to:

- *Identify and label the layers of the epidermis.*
- *Discuss the types of cells found in each epidermal layer.*
- *Differentiate between the structures and functions of the epidermis, dermis, and hypodermis.*
- *Explain the roles of melanocytes in skin pigmentation.*
- *Construct a theory of why tattoos are not placed in the epidermis.*
- *Appraise fingerprints and point out the layers of the skin creating the ridges.*
- *Label the parts of a human hair.*
- *Contrast human hair with hair from other animals.*
- *Evaluate different types of rashes and burns.*
- *Hypothesize who you believe the thief to be and deduce which suspect best fits the criteria based on the evidence gathered at the crime scene.*

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After constructing the learning goals for the lab, a lab activity task was assigned to each objective. For example, looking at microscope slides of both pigmented and non-pigmented skin as well as skin that is tattooed would meet the goals regarding skin layers. Table 1 exemplifies how commonly used materials from the lab can be matched with pieces of evidence that could be used in a crime scene. In this way, past successful lab activities and their accompanying materials could be inserted into an engaging storyline that meets the specific goals of the lab. Note that the materials listed in Table 1 are not an exhaustive list of the possibilities of resources that could be used but offers ideas and a framework to guide unique lab experiences.

Teacher Preparation-Hands-on Component

Preparation for the lab used both purchased supplies and materials produced by the instructor. The items listed "to purchase" in Table 1 are commonly present in many anatomy labs but may need to be relabeled to fit with the story. For example, the slide labeled "Stratified Squamous Epithelium" or "Skin" from the manufacturer should be relabeled "Sample Skin" to indicate that this is skin from the crime scene. Slides labeled "Pigmented or Nonpigmented Skin" from the manufacturer should be relabeled as "Reference Skin" so that students know to use these as a comparison for the crime scene evidence. Table 1 summarizes the materials used in the example integumentary system lab that are assembled into an "Evidence Box" and a "Reference Box" for students. Students compared the samples in the "Evidence Box" with the materials in the "Reference Box" and made decisions about the identity of the thief. For online sections, this "Evidence Box" can be turned into a digital format, such as a Power Point presentation, but this format loses the advantages of hands-on learning.

Material	Purchase	Produce	Produce Instructions	Label or Relabel
Slide: Stratified Squamous Epithelium or Skin	Yes			**Sample #1:** Skin from Crime Scene
Slide: Non-pigmented Skin	Yes			**Reference #2:** Skin-Non-pigmented
Slide: Pigmented Skin	Yes			**Reference #3:** Skin-Pigmented
Slide: Tattooed Skin	Yes			**Reference #4:** Tattooed Skin
Pictures of Rashes: ➤ blister ➤ vesicular ➤ bullae ➤ pustule ➤ papule ➤ fissure	No	Yes	Print pictures of each "rash" and glue them to individual notecards.	**Rash References:** #1-6
Picture of Degrees of Burns	No	Yes	Print pictures of first, second, and third-degree burns	**Burn References:** #1-3
Picture of a forearm with poison ivy (vesicular rash)	No	Yes	Print a picture of an arm with poison ivy	**Evidence #2:** Rash described from crime scene
Picture of Fingerprint	No	Yes	Create a card with a fingerprint - You will need two of these; one from the crime scene and one as a reference	**Evidence #3:** Fingerprint from crime scene
Reference Fingerprints	No	Yes	Produce from different people or print three different fingerprints and glue to a notecard	**Reference Fingerprints:** #1-Carl Circle #2-Sally Square #3-Tony Triangle
Fingerprint Ink Pad and Magnifier	Yes			
Slide-Evidence Hair	Maybe	Maybe	You can purchase this slide or produce it by gluing human hair with clear glue to a microscope slide.	**Evidence #4:** Hair from crime scene
Slide(s)-Reference Hair Slides-Hair Comparison Microscope Slides ➤ cat hair ➤ sheep hair (wool) ➤ human hair	Yes			**Reference Hair Slides-** #1- Cat Hair #2-Sheep Wool #3- Human Hair

Table 1. *Materials Needed for Hands-on Storyline Integumentary System Lab*

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Classroom Management

All materials, except for the hands-on manipulatives, were available to the students electronically through the university's Learning Management System (LMS). Pre-Lab background information for this lab was delivered to students through an online presentation that introduced students to the basics of the integumentary system. In addition, students were assigned online, pre-lab homework to be completed prior to coming to the lab (Table 2). The physiology of the integumentary system was more deeply explored in lecture, so students came to lab prepared to learn and to work. The lab session started with a short (5-10 question) quiz to hold students accountable for the pre-lab material. Once the quiz was complete students were prompted to begin the hands-on case study lab activity.

Students worked in groups to perform the hands-on case study lab activity and were encouraged to use their electronic devices, lab materials and e-textbooks to solicit information. Each section of the lab began with a series of discussion questions that students discussed and answered before progressing to the hands-on part of the crime scene analysis. The instructor circulated through the lab interacting with the lab groups, making sure that students were discussing lab questions before beginning the lab, asking probing questions, and guiding instruction.

Student Perception of the Hands-on Case Study

After completing the "Worst Thief Ever" lab, students were assigned a voluntary, short Qualtrics (https://www.qualtrics.com/ survey about their perceptions of how the storyline of the crime scene affected their engagement, interest, and ability to make connections or their learning of the material. The survey was composed of 5 multiple choice questions and open-ended question about what students liked about including the storyline in the lab and was made available through the course LMS. The project was approved by the Internal Review Board (IRB) of Western Kentucky University (#1951249-1), and informed consent was obtained from all participants.

Results

Students (n=132) were surveyed on how using a storyline as a pedagogical tool in the lab affected their 1) interest in the topic, 2) connections between anatomy and the real world, 3) perceived learning of the material and 4) engagement with the content. Eighty-six percent of students surveyed reported that the storyline of "catching the thief" increased their interest in learning about the integumentary system compared to looking at the slides without context. Eighty-eight percent of students replied that the storyline helped them make connections about the integumentary system and the real world. Sixty-three percent of students thought that the storyline helped them learn the material better while 29% were neutral on this point. Only 8% disagreed that the storyline helped them master the material about the integumentary system. When students were probed about how the storyline affected their engagement in the lab, 83% stated that they had higher levels of engagement with the material because of the storyline.

Timeframe	Roles of Instructor	Student Involvement
Pre-Lab	Post online pre-lab presentation Post online homework	Watch and learn pre-lab material Complete pre-lab homework
During Lab	Administer short quiz Interact with student groups	Take content quiz Engage with groups to use the materials in lab to complete the lab exercise

Table 2. *Overview of the Structure of the Example Lab*

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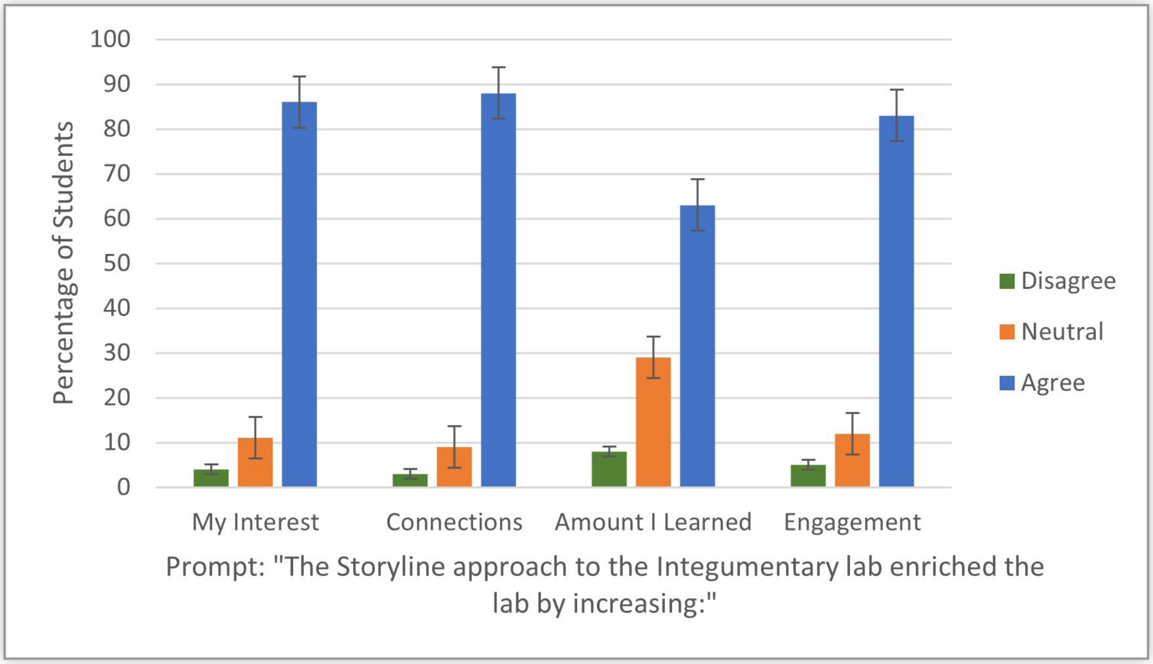

Figure 2. *Student responses to survey about how storyline impacted the integumentary system lab. This figure shows student responses to survey items regarding 1) interest in the topic, 2) connections between anatomy and the real world, 3) perceived learning of the material and 4) engagement with the content.*

When asked to choose how the storyline impacted the integumentary system lab session, 61% of students said that the storyline helped them make connections to the real world, 28% of students reported that the storyline made the topic more interesting/engaging, while only 2% did not like the storyline aspect of the lab.

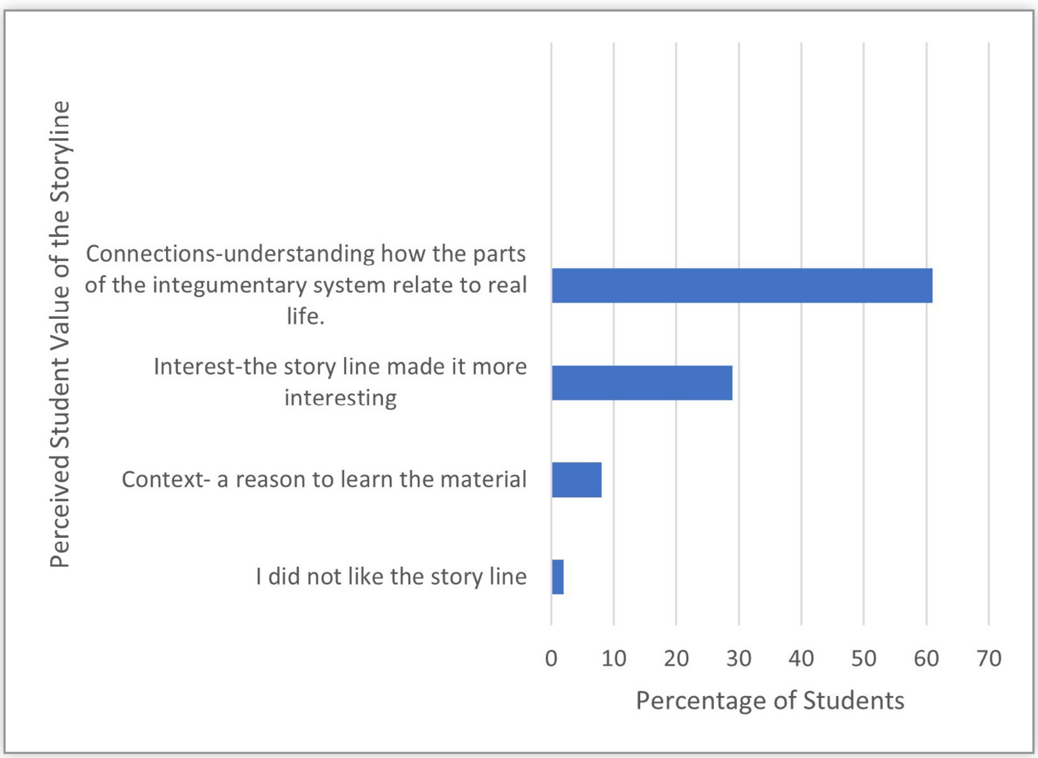

Figure 3. *Student perception of the main value the storyline added to the integumentary system lab. This figure reports student perceptions of the value that the storyline added to the integumentary system lab.1) Connections between anatomy and the real world, 2) storyline made the content more interesting, 3) storyline provided context, a reason to learn the material, 4) students didn't like the storyline.*

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The responses to an open-ended prompt exploring how the storyline impacted their perception of the integumentary system lab were positive. One student wrote *"I love true crime already, so I really enjoyed doing this activity. It was beneficial because you look for smaller differences and have to know what the differences mean in order to solve the case; therefore, it requires more thinking and engages the students more. For example, the skin sample from the crime scene had more melanin being carried by the keratinocytes than someone who is lighter in complexion. The storyline idea engages students more and encourages them to learn. For me, it's hard not to fall asleep and often catch myself wondering because it's kind of boring-the material is interesting, it's just difficult to force myself to pay attention. With this, I was doing something, so it encouraged me to think and made me super excited to learn."* Another student reported, *"It gave me an incentive to complete and fully participate in the lab rather than just learning. I thought it was interesting when we looked at slides from the crime scene under the microscope and compared them to sample/control slides"*. Another student suggested that the storyline improved collaboration between group members when he/she said, *"It helped me make connections with the material to make how and why connections. Secondly, I feel it made my lab group help work and communicate better all at once because of the interesting teamwork establish to learn and "find the culprit!""* While these are just a few of the comments written about the storyline aspect of the lab, most of the open-ended comments were positive. During the lab, the room was bustling with discussion, participation, and energy as students engaged with the materials.

Discussion

Selecting and implementing the best pedagogical approach for teaching anatomical concepts can be challenging. Studies suggest that active learning strategies support student achievement by engaging students in learning (Cavanagh et al. 2018; Freeman et al. 2014; Hodges 2020; Wieman 2014). However, simply doing tasks does not ensure that learning takes place (Andrews et al. 2011). There is a need for students to invest in the activity, meaning that it must connect to the student on an emotional level (be interesting) and a behavioral level (must be fun), and the time invested in the activity needs to payoff (Cavanagh, et al. 2016; Hodges 2020). From a learning perspective, students need to make connections to the real world and be able to apply their knowledge to novel situations (Sevian et al. 2018). Adding a collaborative layer to an activity, by having students to work in groups, increases student success by prompting deeper discussions and the ability to rely on others to help answer hard questions (Bitskinashvili 2018; Nokes-Malach et al. 2015).

The storyline approach to hands-on learning presented in this paper contains the components of effective active learning. Most students reported that the storyline approach increased both their interest and engagement in the topic compared to if they had just looked at the slides (done an activity) alone (Figures 1 and 2). It is not surprising that the greatest reported effect of using a storyline was on students making connections to the real world. Instead of looking at and memorizing layers of skin, students were challenged to learn the anatomy of the skin with the goal of recognizing identifiers of the thief.

Students were intrigued to find tattoo ink in the dermis and quickly drew the conclusion that tattoos placed in the epidermis would not last. Many students shared their own tattoo experience with their groups. The same was true of the fingerprint analysis. While understanding the dermal papillae and epidermal ridges, they had to intently study these to determine the fingerprint pattern. They were eager to make their own fingerprints and compare them with the "reference samples". Several students plucked out one of their own hairs and examined it under the microscope, comparing it to the reference slides as well. Students were interested and engaged and made connections to the real world. What could have been a stale, boring lab became entertaining and educational by the addition of the storyline.

Conversely, adding a hands-on component to a simple case study or to a storyline can increase student involvement and achievement (Bretz 2019; Hofstein and Mamlok-Naaman 2007; McDaniel and Daday 2017; Steger et al. 2020; Wang and Tseng 2018). Case studies are very much like storylines. They offer real-world examples of clinically based scenarios that lead to deep discussions and critical thinking (Gade and Chari 2013; Latif 2014; McFee et al. 2018). Comparing the hands-on storyline approach to the facets of the interactive, constructive, active passive (ICAP) framework for student engagement, the addition of a rich storyline moves students from a "passive" level of engagement, where students receive and recall information, through the "active level" where they manipulate and integrate information, to the "constructive" level where information is generated and transferred and, finally, to the "interactive" level where students discuss and co-create thoughts and information (Chi and Wylie 2014). Moving students to the "interactive" level of engagement on the ICAP framework helps students construct knowledge and work with others to process information at a higher cognitive level (Hodges 2020). It is the merger of the case study/storyline approach with the hands-on lab that makes this method unique and a valuable pedagogical strategy to engage students in minds-on, active learning.

While commercial forensic labs are available for purchase by scientific supply companies, these kits often focus on basic scientific inquiry, observation, and data collection rather than specific topics covered in the anatomy lab, such as the integumentary system. Using simple materials present in most anatomy labs, a storyline can be added to existing labs that increase interest but still meet the specific learning objectives of a course. For example, adding a vial of simulated blood to the storyline highlighted in this

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paper would allow the instructor to focus on characteristics of blood such as blood typing or blood disorders such as sickle cell anemia if these were goals of the course. Since the objectives for this case study focused on the integumentary system, this author did not include blood evidence in the "Evidence Kit". Using this as a storyline framework allows anatomy instructors the flexibility to produce engaging, hands-on labs using materials they already possess to meet learning objects of the course.

This methodology is not limited to a forensic storyline or the integumentary system. A basic histology lab where students look at microscope slides of tissues and learn their characteristics could be modified to become a hospital pathology laboratory where students need to understand the reference slides to diagnose patient diseases and make recommendations for treatment. A bone lab could be converted to an archaeology dig where information about the people who lived in a region could be deduced based on the bone size and structure. Learning bone markings could help students reconstruct the bones to explain how the people lived and died. Adding a storyline to a hands-on standard lab should help to engage students, initiate conversations and stimulate higher order thinking. While the addition of storylines to hands-on labs has many benefits, these advantages could be extended to the digital world. This author challenges commercial e-text and e-materials publishers to incorporate storylines into virtual lab experiences to provide context and engage students during digital simulations and lab activities.

Conclusions

Using a storyline created specifically to cover lab objectives is an effective way to increase student interest in the content and engagement in a hands-on lab. Adding context and intrigue to lab exercises in which students regularly participate, makes students more willing to invest effort in learning the material and ultimately could improve student success. Storylines can be easily added to traditional anatomy lab experiences to meet the goals of the course.

About the Author

Dr. Kerrie McDaniel is an associate professor in the Department of Biology at Western Kentucky University. She is responsible for the Human Anatomy and Physiology program at the university which involves writing curriculum, teaching, managing teaching assistants (TAs), and organizing materials. Her research interests include student learning and engagement, the use of e-texts and e-learning materials, and bolstering the STEM pipeline by inspiring middle school science teachers through the National STEM Scholar Program.

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Appendix 1: An Example Hands-On Storyline Integumentary System Lab

The Case:

As a member of the *(insert the name of your city or college here*) Task Force on crime, it is your job to help keep the city safe. You have been especially busy lately because of a criminal dubbed the Bonehead Bandit. This crook is responsible for a series of robberies of local business and well-known residences in the area. He/she is most noted for stealing rare pieces of art. Until recently he/she has remained undetected leaving very little evidence for your task force to work with. Last night, however, an eyewitness got a brief glimpse of the thief as he/she slipped out the back door of the First National Federal City Bank downtown. While the thief escaped with a lesser-known painting by Grant Wood entitled "Southern Gothic", he/she left a few clues.

The Suspects:

- **Carl Circle**: Carl is a gardener who landscapes for many of the businesses and residences in the area. He lives in a very nice condominium and drives a new corvette. His brother works for the Metropolitan Gallery of Art in New York City. Carl is Caucasian with curly brown hair, gray eyes and a lizard tattoo on his forearm. He has two indoor calico cats and a goldfish.
- **Sally Square**: Sally is a teller at the Third National People's Bank. She was recently passed over for a promotion for manager. She lives in a nice subdivision in a single dwelling home with her sister, Susan. Sally studied art in college and participates in local art shows at the Capital Arts Theatre. In addition to painting, Sally knits sweaters out of sheep's wool that she spins into yarn. Sally has recently purchased tickets for a European cruise to visit her cousin in Poland, where many of her family is from. Sally is Caucasian and has curly blonde hair and green eyes. She has eczema but no pets.
- **Tony Triangle**: Tony is a local real estate developer. He specializes in strip malls. Recently his three largest tenants have pulled out of their lease leaving Tony low on funds. He has a grudge against three of the banks in town because they are putting pressure on him to pay his loans. Tony lives in a penthouse apartment in one of his properties with his girlfriend, Fritzy. Tony is Caucasian and has straight black hair, and brown eyes. He has a tattoo of a clipper ship on his arm. He recently returned from a "camping trip" deep in the woods where he was checking on his "crop". He slept in a tent with his associates in an area populated by poison ivy. Tony does not have any pets.

Evidence:

Witness Statement: Rubeus Red	**Report By:** Officer Vesalius
Mr. Red stated that he was taking out the garbage at the First National Federal City Bank when he noticed that that "Southern Gothic" painting was missing from the wall. He quickly glanced and saw a dark figure scurry out the door. He particularly noticed that the culprit was not wearing a glove on his/her left hand and that the hand was covered in some sort of rash. He also noticed that the crook was Caucasian, and that his/her arm was bleeding. The officer examined the doorframe and found a small piece of tissue, presumably from the forearm of the criminal and a clump of hair, both of which were entered into evidence. Mr. Red also noted a dark mole on the back of the culprit's hand.	

Forensic Evidence Collected-Sample from Crime Scene:

Sample	Description	Collected From
1	Skin tissue	Doorframe of bank
2	Description of lesions on hand of culprit	Eyewitness account
3	Fingerprint	From wall near missing painting
4	Oil from fingerprint	Wall near missing painting
4	Hair	Stuck in blood on doorframe
5	DNA • DNA fingerprinting • Ancestry analysis	From skin tissue

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Reference Materials

Reference	Description	Use
1	**Skin Slides** • Nonpigmented Skin • Pigmented Skin • Tattooed Skin	To identify the layers and structures in each layer of the skin to compare to the sample from the crime scene.
2	**Reference Rash Cards** • Blister • Vesicular • Bullae • Pustule • Papule • Fissure	To identify the types of skin lesions and their possible sources
3	**Reference Fingerprints** • Suspect 1 • Suspect 2 • Suspect 3	Compare the fingerprints from the crime scene to the reference prints.
4	**Reference Hair Slides** • Human Hair Slide • Cat Hair Slide • Sheep Hair Slide (Wool) • Curly Hair Slide • Straight Hair Slide	Compare with the hair from the crime scene to determine if the hair is human and if so, if it is straight or curly.

Your Task:

Help the Task Force on Crime solve this mystery by examining the evidence, answering the questions about the evidence as you examine it, and deduce who you believe the thief to be. Complete the evidence analysis form as you carry out your investigation.

1. Skin Tissue Analysis: Skin Layers, Skin Color and Tattoos

A. Analysis Questions. These are questions that you need to be able to answer to analyze the skin taken from the crime scene. Work in your groups and discuss these questions before you start looking at the slides.

- What are the layers of the skin?
- What specific types of cells do you find in each layer?
- What information about the thief do you gain from the microscopic examination of skin from the crime scene?
- What causes skin color?
- Which cells are involved in skin color?
- Where would you find the difference in skin color in the layers of the skin?
- Can a person's skin color change? How?
- What is a tattoo?
- How are tattoos produced?
- Into which skin layer is the ink of a tattoo placed?
- Does it matter which layer of the skin the ink of a tattoo is placed? Why?
- Which cells of the skin would be involved in the immune system of the skin?

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B. Task Instructions

a. Examine the reference slides of skin. Make sure that you can label all the layers.
Draw what you see and label the layers.

- What is the difference in the pigmented and nonpigmented skin reference slide?
- In which layers of the skin do you see these differences?

Draw pigmented skin

Draw nonpigmented skin

b. Examine the Reference slide of tattooed skin. How does this slide differ from the first two reference slides you have observed?

Draw what you see from the tattooed skin reference slide

c. Examine the slide of the skin taken from the crime scene (doorframe). Do you see the same layers in the slide from the crime scene as the reference slides?

Draw the skin from the Crime Scene

d. How is the skin from the crime scene the same and different from the reference slides?
What information do you gain from examining the crime scene skin slide and comparing it with the reference?

C. Does the culprit have a tattoo? How can you tell?

2. <u>Record your results in the Evidence Analysis Form at the end of the lab</u>.

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3. <u>**Hand Lesion Analysis**</u>

A. Analysis Questions. You need to understand the following in order to analyze the lesions observed at the crime scene. Work in your groups to discuss and answer the following questions before you perform your analysis.

- What is the difference between the following?
  - burn
  - blister
  - vesicle
  - bullae
  - pustule
  - papule
  - fissure
- When a blister forms, which two layers separate?
- What are some causes of dermatosis and dermatitis?
- Are all burns caused by heat? What are some other causes?
- Which cells in the skin are responsible for producing moles?
- What is the difference between a mole and a freckle?

B. Task Instructions

a. In your groups look at the reference pictures of the rashes. Discuss what circumstances might lead to those rashes.

b. Examine the picture of the rash derived from the eyewitness account of the crime scene. Compare it with other types of rashes. What type of rash is found on the thief?

c. Hypothesize how the thief might have obtained his/her rash.

C. Results Analysis-Record your results in the Evidence Analysis Form at the end of the lab.

4. <u>**Fingerprint Analysis**</u>

A. Analysis Questions/Background about fingerprints. Work in your group to discuss and answer these questions before you examine the fingerprints.

- What produces a fingerprint?
- Which skin layers are involved in producing a fingerprint?
- How do fingerprints differ from each other?
- Diagram the layers of the skin involved in producing a fingerprint.
- What do the following terms mean with regard to fingerprint analysis? What forms these shapes on a fingerprint?
  - Arch
  - Whorl
  - Loop
  - Tent Arch
  - Pocket Loop
  - Double Loop

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B. Task Instructions

a. Use the jeweler's loupe (magnifying glass) to examine the fingerprints of the three suspects in the reference slide box.

b. Examine the fingerprint from the crime scene and compare it to the reference slides? Do any of the fingerprints match? What does this mean? Does the evidence point to a specific suspect?

c. Use the ink pad to produce your own fingerprints and examine them for shape. Describe your fingerprints.

Use the ink pad to produce your own fingerprint. What shapes do you see?

C. Results Analysis-Record your data in the Evidence Analysis Form at the end of the lab.

5. <u>Hair Examination</u>

A. Analysis Questions and Background about hair.

In your groups discuss and answer the following questions before you start looking at the slides.

- What are the layers of human hair?
- What are the structures of the human hair?
- Why does it not hurt when you get your hair cut but it does hurt when it is pulled?
- Could we get DNA evidence from a hair?
- How does human hair differ from animal hair?
- What produces hair color? Can you see this under a microscope?
- How does straight hair differ from curly hair under the microscope?
- Does the hair look different under the microscope than you expected? In what way?

B. Task Instructions

a. In your groups, examine the hair samples provided in the Reference slide kit. Identify the parts of the hair. Draw and label what you see.

Human Hair

Cat Hair

Sheep Hair (Wool)

Straight Hair

Curly Hair

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b. Examine the hair from the crime scene. Draw and label what you see below.

Hair from Crime Scene

c. Is the hair found at the crime scene human hair? If not, what type is it?

d. Can you tell if the hair is straight or curly or what color it is?

e. What information does the hair from the crime scene provide you to help you solve the crime?

f. Pull out a strand and look at your own hair under the microscope. How does this differ from the slide?

Evidence Analysis Form

Task Force on Crime Members: ____

Section Number: __________

Results

		Description of Results from Crime Scene	Results/Observations
1	**Skin**	Layers (What skin layers did you observe): Pigmentation: Was the skin pigmented? Tattoo (Present/Absent):	
2	**Lesion**	Type of Lesions: What types of skin lesions were observed from crime scene? Probable cause of lesions?	
3	**Fingerprint**	What shapes were observed from the friction ridges from the crime scene fingerprint? Arch Tent Arch Whorl Left Pocket Loop Left Loop Double Loop Right Loop Right Pocket Loop	
5	**Hair**	Was the hair from the crime scene human? Cat? Sheep? Other? Could you tell the color of the hair? Was the hair straight or curly?	

Based on the evidence that you analyzed, who do you think the thief is?

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Appendix 2: Hands-on Storyline Scenario Template

This template outlines steps towards turning a basic anatomy lab into an engaging experience based on a crime scene storyline. The example used in this paper is a lab for the integumentary system. Many different anatomy labs could be modified to fit this format.

Step 1: What are the goals for this lab?

Step 2: What lab do you usually conduct to meet these goals?

Step 3: What materials do you have available or can you purchase/procure to conduct this lab.

Step 4: How can these activities/materials be used in a crime scene? Turn the materials into crime scene evidence.

Step 5: Modify crime scene storyline to fit your needs.

EXAMPLE. From typical integumentary system lab

Step 1: What are the goals for this lab (these may include HAPS learning or process outcomes)?

Examples: *Goals for the integumentary system lab* may include (others listed in body of paper):

- Identify and label the layers of the epidermis.
- Differentiate between the structures and functions of the epidermis, dermis, and hypodermis.
- Explain the roles of melanocytes in skin pigmentation.
- Construct a theory of why tattoos are not placed in the epidermis.
- Appraise fingerprints and point out the layers of the skin creating the ridges (dermal papillae and epidermal pegs).
- Label the parts of a human hair.

Step 2: What lab do you usually conduct to meet these goals?

Examples: Typical activities for the integumentary system lab may include:

- Use microscopes to examine prepared slides of skin.
- Look at different fingerprints and compare and contrast them.
- Use microscopes to observe prepared slides of hair from humans

Step 3: What materials do you have available or can purchase/procure to conduct this lab.

Examples: Typical materials for the integumentary system lab may include:

- Prepared microscope slides of skin and hair
- Images of different fingerprints

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Step 4: How can these activities/materials be used in a crime scene? Turn the materials into crime scene evidence.

Example: How the goals and materials from a typical integumentary system lab can be turned into a lab with a crime scene storyline.

Goal	Material	Evidence
Example		
-Identify layers of epidermis -Rolls of melanocytes -Location of tattoo -Dermal Papillae/epidermal pegs identification	Prepared Microscope slides: a. Pigmented skin b. Non-pigmented skin c. Tattooed skin d. A second copy of one of the slides above	These will serve as reference slides. I will add a fourth slide where I cover up the label as the crime scene skin. Students will compare crime scene to references.
-Fingerprints-analysis and identification of dermal papillae and epidermal ridges	Fingerprint Cards a. Laminated cards with various fingerprints (from suspects) b. Laminated card from crime scene Ink to produce own fingerprints a. Compare own fingerprint with cards	The laminated cards from the suspects will serves as references to compare crime scene fingerprints.
-Label the parts of a human hair	Prepared Microscope slides: a. Human hair b. Hair from sheep and cat	In the storyline, one of the suspects knits with wool yarn and the other has a cat. Students will compare crime scene hair with references.

Step 5: Modify Crime Scene storyline to fit your needs.

Example: Change the names of the suspects so that they are interesting for your students, such as the names of other faculty members in the department. Provide only the evidence that will help the students meet the goals of the lab.

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Improved Understanding of Clinical Correlates with In-Situ Prosections

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Abstract

The correlation of anatomy with pathophysiology is not intuitive for many medical students. Despite detailed cadaver dissections and three-dimensional models, board-style clinical correlation questions can still be challenging for first-year students. To facilitate understanding in this regard, prosections were developed to illustrate the clinical correlations taught in the upper extremity, thorax, and head and neck. Brief, focused videos were introduced into lecture material leading to a 37% relative gain in performance on 30 exam items covering the related clinical correlations. https://doi.org/10.21692/haps.2023.008

Key words: In-situ dissection; clinical correlations; structure-function; cadaver tumescence; tumescent dissection

Introduction

Gross anatomy taught to first-year medical students lays the foundation for a lifetime of medical practice. As students learn to identify many different anatomical structures through the dissection of their cadaver donors, they are also introduced to clinical correlations. Initially, such correlations between anatomical structures and related medical scenarios serve to pique student interest and increase the retention of anatomical information. Later, they become the primary reason for their anatomy education. They underly board examination questions which in turn, mirror the ability of a physician to make a diagnosis. Clinical correlations require the higher order thinking that integrates the concrete with the abstract, structure with function.

While supplemental learning technology, such as 3-D models, interactive 3-D software, and virtual anatomy programs, have been shown to help students understand three-dimensional structure (Zilverschoon et al. 2021), there is still room for improvement with the integration of this structure with function. Along these lines, we began using special "in-situ" dissections to integrate structure with clinical correlations. In-situ dissections are thorough dissections that maintain the interrelationships between adjacent, deep, and overlying structures. These dissections allowed for a visual representation of structure as it relates to function and the graphic illustration of clinical correlations. We incorporated videos of these dissections into lecture material resulting in a marked improvement in student performance on related exam items.

Description

In-situ dissection videos were developed in the head and neck, thorax, root of the neck, and upper extremity. The use of tumescence, the infusion of wetting solution along tissue planes and fine structures, facilitated the mobilization of structures while maintaining their integrity (Loomis et al. 2022). No muscles were transected, fascial planes were preserved, and soft tissues uncovered and mobilized only to the extent needed to reveal multiple layers at once, demonstrating all pertinent structures without loss of their interrelationships. The video clip of each area usually began with a view of intact skin which was then reflected and underlying tissue planes and muscles retracted as needed to visualize pertinent anatomy.

To maintain in-situ relationships in the thoracic cavity, a median sternotomy was performed and the clavicles and ribs retracted. The heart and lungs were kept in place and the paths of vessels and nerves cleaned through the neck and chest, taking down the internal thoracic arteries from the sternum. Tumescence was again used to follow the phrenic nerve from the chest to the neck, infusing wetting solution just over the perineurium to mobilize the nerve's path without damaging its structure or adjacent anatomy. Areas of heart and lung auscultation and extents of pleural recesses relative to overlying ribs were demonstrated in the videos by opening and closing the rib cage over the structures. The cardiopulmonary relationships were highlighted at the hila of lungs, along with the spatial relationships of the vagus and phrenic nerves.

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The root of neck was exposed with reflection of the clavicles keeping the sternocleidomastoid muscles attached. To appreciate clinical scenarios of nerve compression in the upper extremity, nerves were visualized from the scalene muscles through the axilla, arm, and forearm into the hand.

Discussion

To better meet the need of medical students to understand clinical scenarios, curricula have undergone horizontal and vertical integration, increasing the focus on clinical correlations in anatomy instruction. The issue of how to most effectively and efficiently teach this expanded integration in the face of shrinking time and monetary resources has been at the center of much recent medical education research (Chang et al. 2022). Despite a plethora of supplemental resources available to students, cadaver dissection is still the gold standard, especially for focused individualized review, as when surgical residents need to refresh anatomical knowledge prior to assisting in surgery (Streith et al. 2022).

When students self-direct their dissections however, they may miss key features. Supplementing the traditional two-dimensional atlas with three-dimensional models and plastinated specimens has significantly expanded the appreciation of complex anatomical structures from multiple perspectives. With mixed-reality programs, students can walk around a virtual image that they perceive in their headset (Baratz et al. 2022). Despite differences between various types of three-dimensional models, most have provided significant improvement in overall student learning (Mogali et al. 2021; Radzi et al. 2022). The technology does not benefit all students, however. Spinning virtual structures can be disorienting and not helpful to students with decreased spatial ability (Labranche et al. 2021; Roach et al. 2021), and headsets can cause motion sickness and headaches, limiting the duration of their use (Kuehn 2018).

One way in which all approaches to anatomy can be limited is "not seeing the forest for the trees." Appreciating the interrelationship between anatomical structures is key to understanding the cause and effect inherent in clinical correlations. As fine anatomical details are learned, whether it be by meticulous cadaver dissection, three-dimensional models and plastination specimens, or mixed reality, there is a risk of students learning structures in isolation.

The pectoralis minor muscle is reflected to fully visualize the subclavian artery whose sequential branches are seen and memorized, but the critical relationship between that muscle and the brachial plexus is lost. Forearm muscles are reflected in layers from superficial to intermediate to deep in order to see the muscles in their entirety and to follow arteries and nerves along their longitudinal paths, but the visual impact of seeing nerves tucked beneath muscle and fascial edges where they can be compressed is lost. Fascia is removed to better visualize muscle fibers, but the dynamic of compartment syndrome is more difficult to conceptualize. The heart and lungs are removed or virtual representations of them spun around on a screen to see their anatomy from all sides, but the interplay between heart and lung is less clearly appreciated. The concept of how a mediastinal shift would reduce venous return to the right atrium remains as abstract as before the dissection or mixed reality session.

Traditional dissections and three-dimensional models, while very helpful to learn the bulk of anatomical details, can leave students needing to make a mental jump to understand the more abstract clinical correlation. Having learned structures in isolation or as separated layers, this can be a very difficult task. Seasoned anatomists can look at the four layers of the plantar foot and intuitively reconstruct them in their minds, but to the students, they are often four distinct layers memorized as isolated entities. Medical students become very proficient at drawing the branches of the brachial plexus, however, integrating this structure into its environment to deduce the answer to clinical questions requires further development of critical thinking skills. These prosections were designed to provide a sequence of concrete visual steps to foster that abstract mental process of integration. Solving such clinical questions makes up much of medical students' board examinations, as well as the bulk of the diagnostic skill they will require as physicians, so it is essential to help students transition to this higher order thinking whenever possible.

Since prosections have been shown to be equally effective at teaching anatomy as student dissections (Koh et al. 2023; Lackey et al. 2020), we designed our special prosections that focused on the clinical correlations with which the students had the most trouble. Concise, edited videos of prosections are effective teaching tools that are generally well-received by students (Dharamsi et al. 2022; Hadie et al. 2019; Natsis et al. 2022). Focusing on actual nerve compression sites such as the anterior interosseus nerve beneath the intact flexor digitorum superficialis (Figure 1) and the radial nerve at the proximal edge of the supinator (Figure 2), our brief videos integrated the concrete anatomical structures with the more abstract notions of dysfunction and levels of nerve compression.

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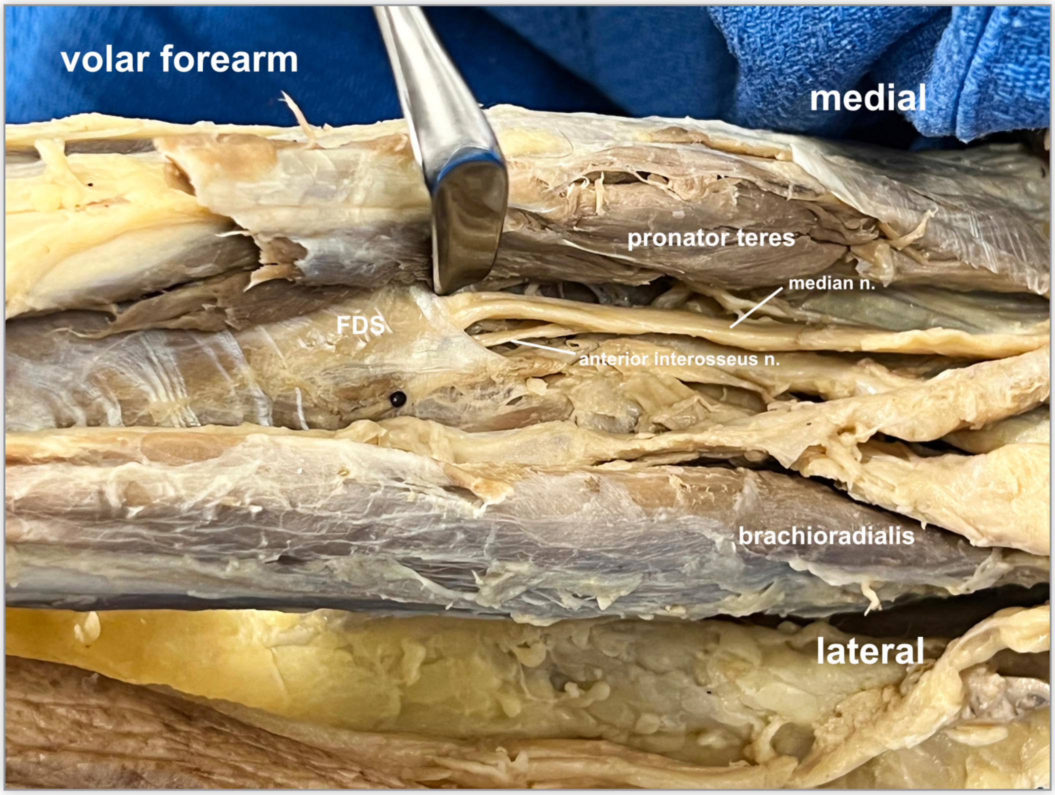

Figure 1. *The volar forearm was oriented with in-situ skin and soft tissue and the cubital fossa and thumb in view, then the video followed the median nerve from the arm, under the belly of the pronator teres, retracted with minimal mobilization, to the flexor digitorum superficialis which was kept intact. It was noted at what levels the median nerve innervated the pronator and other volar muscles, and at what levels it might be compressed. The scenario in which the anterior interosseus nerve was compressed but not the remainder of the median nerve could be appreciated by its position beneath the tight fibrous band of the flexor digitorum superficialis.*

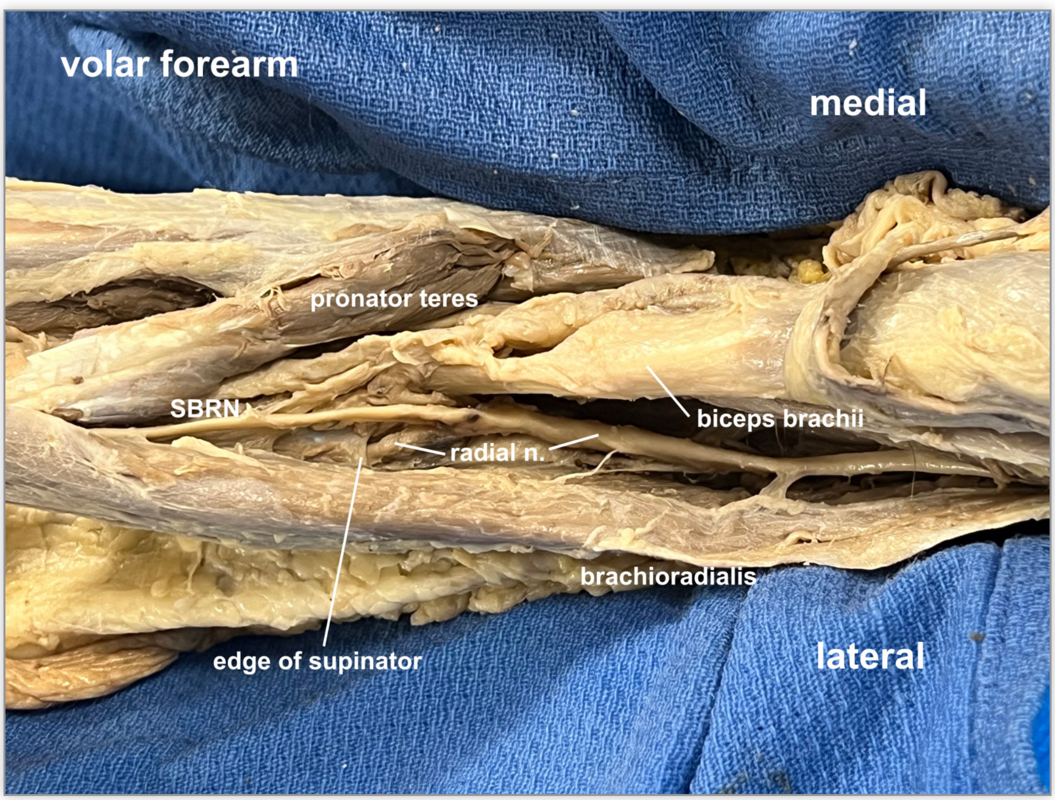

Figure 2. *With the pronator teres muscle returned to its in-situ position, the brachioradialis muscle was retracted to demonstrate the radial nerve which was followed from its emergence from the spiral groove of the humerus across the elbow. Radial nerve innervation of the brachioradialis and the extensor carpi radialis longus and brevis muscles was noted proximal to the site of compression of the deep radial nerve branch beneath the fibrous band of the supinator muscle. Also noted was the superficial branch above the supinator. Both can help students understand why radial nerve compression in the proximal forearm does not cause wrist drop nor loss of sensation, unlike a mid-shaft humeral fracture which causes both.*

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With visceral organs still in place, predicting the extents of visceral/parietal spaces and their relationships to the overlying ribs became more intuitive. The abstract concepts of cardiac pathophysiology were visibly integrated with the concrete anatomy of the heart and lungs in the chest. The right atrium and superior and inferior vena cava were portrayed not as isolated structures, but as dynamic sources of preload affected by heart position and the changing pressures of the intrathoracic cavity. The visual impact of such a demonstration can help students make the jump from the concrete to the abstract, assimilating the two. In addition to directly visualizing the site of the ribs over the apex of the heart, viewing the in-situ heart in a mirror helped explain the orientation of an ultrasound image at this site (Figure 3). Intact lungs were inflated and deflated correlating function with clinical scenarios. In the CNS, the meninges, vascular territories, and cranial nerve pathways were also appreciated in videos.

Multiple brief videos focused on the interrelationships of key anatomical structures in-situ were introduced into lectures covering upper extremity, cardiopulmonary, and neuroanatomy clinical correlations. These videos were also available to students individually online allowing for quick review and orientation when studying practice questions.

To determine if and to what extent these short in-situ dissection videos helped students answer higher order questions, student performance on related exam items in the Fall semester of 2022 (n=154) was compared to that of students from the Fall semester of 2021 (n=114) in which the in-situ videos were not available (Appendix 1). The sessions were taught by the same professor, over the same amount of time, using the same material, except for the inclusion of the in-situ videos. Thirty higher order exam items covering clinical correlations in the upper extremity, cardiovascular, and nervous system were compared.

The average percentage of the class which answered the questions correctly increased from 60% without the in-situ dissection videos to 82% with the videos, a gain of 22 percentage points, or a 37% relative gain. To test the hypothesis that the difference in score from 2021 to 2022 was significantly greater for items which benefited from the videos a one-sided t-test for two dependent means was performed. The results from 2021 (M=59.5, SD=18.6) compared

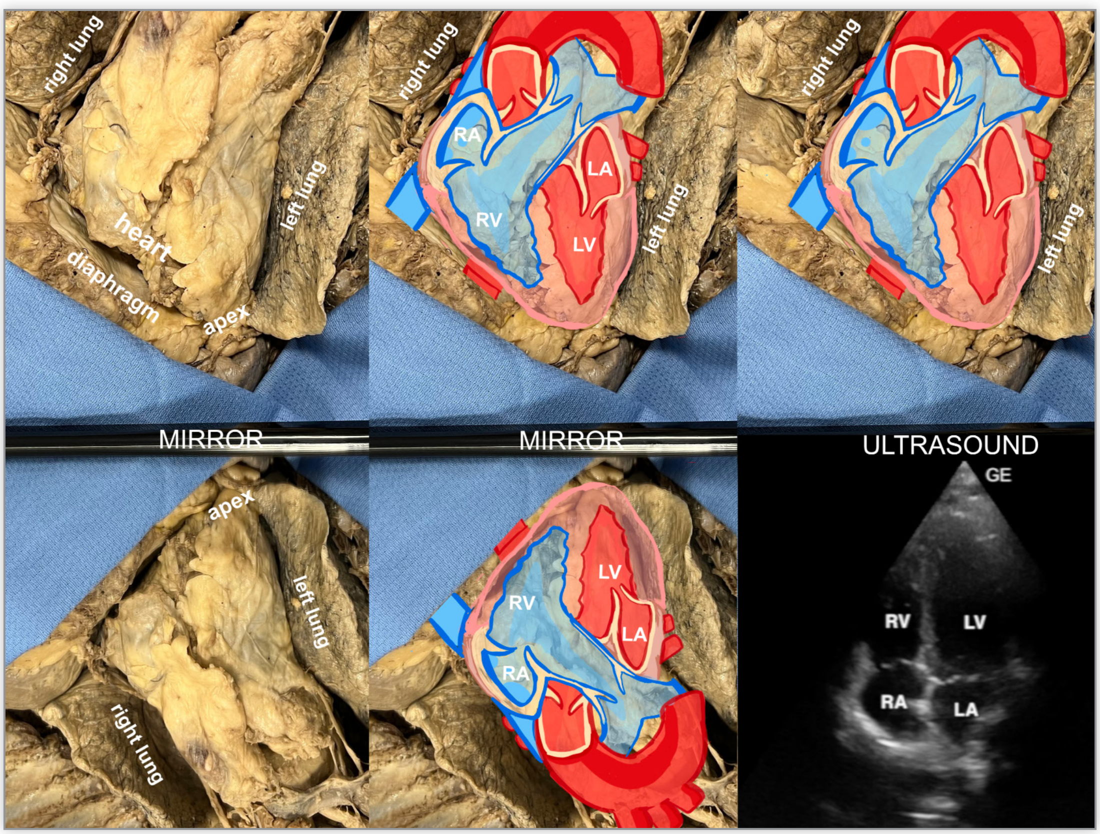

Figure 3. *This video began by orienting the in-situ heart and lungs. A mirror was then held up to the apex of the heart to demonstrate its reflection. Schematics of the heart's chambers were then overlaid on both the direct view of the heart and its reflection. This reflected schematic correlated nicely with a juxtaposed apex ultrasound image.*

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to 2022 (M=81.8, SD=12.7) indicated that the 2022 scores were significantly greater, t(29)=7.8, p<.00001.

Of note was a scheduling change from an eighteen-week course running concomitantly with a cellular biology course, to a nine-week course without the concomitant cellular biology course. While this block scheduling could have affected the change in exam performance, there was no significant improvement in the performance on the eleven other items which covered gross anatomy between 2021 (M=83.8, SD=12.6) and 2022 (M=84.9, SD=8.2), t(10)=0.27, p=.39 (Figure 4, Table 1). The performance on those items was already in the range of 84% for both years however, so there was not as much room for improvement compared to items covered by the in-situ videos, which had a 2021 average of 59.5%.

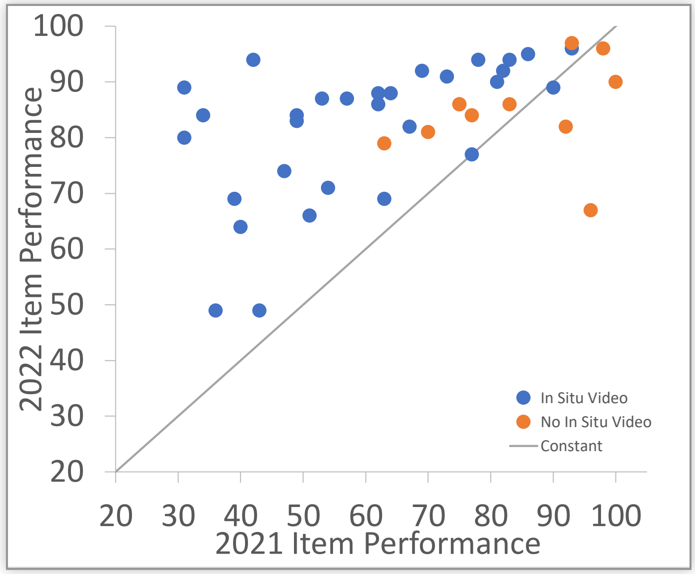

Figure 4. *Exam item performance with in-situ dissection videos and without.*

Learning objective	Clinical correlation covered	Methods previously utilized	In-situ video added	Point change (%)
Correlate the dural blood supply with intracranial bleeding.	Middle meningeal artery injury and presentation	Atlas drawings, CTs, polling questions	No new videos added	- 10
Outline the cerebral ventricles and correlate with sites of obstruction	HA, pineal tumor, site of obstruction	Atlas, CT, MRI, donor images, polling questions	No new videos added	+ 3
Outline the bones and sutures of the skull and the names of their points of intersection	Skull fracture crossing lambdoid suture	Atlas, CT, bone models	none	- 10
Correlate the vessels supplying cortical and brainstem regions with the function of those regions.	Stroke with loss of sensation and motor function to lower extremities	Atlas, drawings, imaging, gross brain photos and videos tracing regions	No new videos added	+ 16
Predict nerve lesions and symptoms resulting from cerebral aneurysms.	Posterior communicating artery aneurysm	Atlas, drawings, imaging, gross brain photos and videos tracing regions	No new videos added	+ 11
Map out coronary artery and vein locations.	Vein traveling with anterior interventricular artery (LAD)	Atlas, drawings, angiograms	none	- 2
Correlate structures in the thorax with their function.	Identifying structures on CT crossing diaphragm	Atlas, diagrams, imaging	none	- 29
Outline the normal and abnormal vertebral curves.	Description of scoliosis	Atlas, charts, imaging, bone models	none	+ 7
Correlate the segmental and continuous ligaments of the spine with their function	Spinal tap needle piercing ligamentum flavum	Atlas, diagrams, bone models	none	+ 11
Correlate the segmental and continuous ligaments of the spine with their function.	Cervical spine fracture with injury to long ligament	Atlas, diagrams, bone models, imaging	none	+ 11
Correlate the attachments, blood supply and innervation of the superficial and deep back muscles with their function.	Injury to trapezius in motor vehicle accident, weakness of shoulder elevation	Atlas, diagrams, clinical pearls, polling questions	none	+ 4
			Average	**+1**

Table 1. *Learning objectives of sessions that had no videos added in 2022 shown with their associated clinical correlations, the methods used, and the difference in the percentage of the class answering the exam item correctly. Overall, there was not a significant difference between 2021 and 2022, although the performance was already quite high on these items.*

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Conclusion

For medical students to become sound, safe physicians, the concrete anatomy that will someday be palpated beneath the examining hand or perceived through the stethoscope must be integrated with abstract concepts such as pressure gradients, vascular territories, and levels of neurological injury. In-situ dissection videos presenting focused, impactful representations of clinical correlations facilitated this integration in our anatomy course in which a 37% relative gain in performance on exam items related to upper extremity, cardiovascular, and neuroanatomy clinical correlations was observed.

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Appendix 1: Learning objectives of sessions with their associated clinical correlations, the previous methods used, and the in-situ dissection videos that were added with the subsequent point-change in the percentage of the class who answered the associated exam item correctly.

The average increase of twenty-two percentage points was from 60% to 82%, a 37% relative gain.

Learning objective	Clinical correlation covered	Methods previously utilized	In-situ donor video added	Point Change (%)
Correlate clinical signs with cranial nerve somatic and visceral function to localize sites of injury.	Brainstem stroke, ventral caudal pons: CN VI presentation	Atlas images, diagrams, charts, clinical pearl highlights polling questions	Video of gross brain tracing cranial nerves and correlating with clinical scenarios	+ 24
Correlate the brain's venous drainage with common types of intracranial bleeding.	Subdural hematoma, origin of bleed: bridging veins	Atlas images, diagrams, charts, imaging, clinical pearl highlights	Video of calvarium, dura, bridging veins entering sup sag sinus	+ 30
Predict underlying cardiac structures based on surface chest anatomy	Heart sound auscultation at sites on chest wall	Atlas images, diagrams, charts, imaging, clinical pearl highlights	Video of chest opening directly over heart, demonstrating intercostal spaces	+ 3
Discern the azygous venous system and its relationship to the thoracic duct, esophagus, and superior vena cava.	Thoracic duct injury in posterior mediastinum	Atlas images, diagrams, charts, clinical pearl highlights polling questions	Videos exploring chest, heart and lungs in place, retracting heart and esophagus to see thoracic duct	+ 15
Deduce clinical scenarios as they relate to the anatomy of the vertebral column, spinal cord, and meninges.	Injury vertebral artery transverse process	Imaging, atlas, diagrams, charts, clinical pearl highlights	Video following vertebral artery from subclavian in chest, overlay pics of cervical vertebrae	+ 27
Deduce where the vagus nerves are located in the mediastinum and their relationship to the thoracic viscera.	Relationships of vagus and phrenic nerves in mediastinum	Atlas diagrams, clinical pearl highlights polling questions	Video tracing vagus nerves from neck through chest	+ 6
Correlate patient presentations with the locations of bone, nerve, or tendon disorders of the shoulder.	Rotator cuff injuries, relationship with subdeltoid bursa	Imaging, atlas diagrams, bone models, charts, clinical pearls, polling	Video exposing rotator cuff by retracting deltoid anterior and posterior, and rotating humerus	+ 35
Discern the peripheral nerves affected by injuries to the upper, lower, medial, lateral, or posterior aspects of the brachial plexus.	Posterior cord crutch injury presentation	Atlas diagrams, charts, drawing brachial plexus, clinical pearl highlights polling questions	Video tracing brachial plexus from scalenes in neck through axilla and to endpoints in upper extremity	+ 18
Discern the venous supply of the upper extremity, pectoral musculature and the breast.	Upper extremity venous drainage, cephalic, basilic	Atlas diagrams, charts, clinical pearl highlights	Video reflecting skin, retracting muscles, following veins from hand to chest/axilla	+ 34
Discern the peripheral nerves affected by injuries to the upper, lower, medial, lateral, or posterior aspects of the brachial plexus.	Lower brachial plexus injury presentation	Atlas diagrams, charts, drawing brachial plexus, clinical pearl highlights, polling questions	Video tracing brachial plexus from scalenes in neck through axilla and to endpoints in upper extremity	+ 24

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Correlate the structure and function of the intrinsic muscles of the hand with normal and abnormal function of the median and ulnar nerves.	Presentation median nerve injury at wrist specific muscle weakness: opponens pollicis	Imaging, atlas, diagrams, charts, clinical pearl highlights polling questions	Videos exploring hand by retracting overlying layers, following nerves, correlating with clinical scenarios	+ 9
Given a loss of function, predict the nerve involved and the site of injury.	Ulnar nerve injury, distinction between cubital tunnel, Guyon's canal, and brachial plexus	Imaging, atlas diagrams, charts, clinical pearl highlights polling questions	Videos tracing nerves from brachial plexus, to elbow, forearm, wrist, and hand	+ 6
Distinguish between the layers of the thoracic wall from the skin to the parietal pleura, subdivisions of the parietal pleura, the pleural space, and the visceral pleura.	Site of pleural tap below lung in mid-axillary line	Imaging, atlas diagrams, charts, clinical pearl highlights polling questions	Video of chest wall opening with median sternotomy, demonstration of pleural recesses, overlying intercostal spaces	+ 52
Predict locations of upper extremity injuries based on physical findings	Serratus anterior denervation: loss of abduction over 100˚	Atlas diagrams, charts, clinical pearl highlights polling	Video of axillary dissection, long thoracic and thoracodorsal nerves highlighted, muscles in place	+ 10
Correlate the structure and function of the intrinsic muscles of the hand with normal and abnormal function of the median and ulnar nerves.	Physical exam testing of deep ulnar nerve: abduction fingers	Atlas diagrams, charts, clinical pearl highlights polling questions	Video following ulnar nerve from forearm, through wrist, superficial and deep branches, with their endpoints	+ 34
Correlate the structure and function of the intrinsic muscles of the hand with normal and abnormal function of the median and ulnar nerves.	Cubital tunnel syndrome, specific muscle weakness, adductor pollicis	Atlas diagrams, charts, clinical pearl highlights polling questions	Videos tracing nerves from brachial plexus, to elbow, forearm, wrist, and hand	+ 50
Discern the superficial and deep palmar arterial arches, their branches, and collateral connections.	Allen test: communication between superior and deep palmar arches	Atlas diagrams, charts, clinical pearl highlights polling questions	Video following radial and ulnar arteries at wrist into hand, superficial arch with deep arch image overlay. Correlated with ultrasound videos	+ 9
Discern the bony and fascial structures of the hand as well as the spaces and bursa.	osteoarthritis of saddle joint with first metacarpal: trapezium	Atlas diagrams, charts, clinical pearl highlights polling questions, bone models in lecture	Videos of wrist dissection, correlation with ultrasound videos	+ 30
Discern the structure and function of, and clinical implications of injury to the flexor and extensor tendons in the wrist and hand.	Laceration over prox phal of thumb, involving which tendon? EPL	Atlas diagrams, charts, clinical pearl highlights polling questions, bone models in lecture	Video tracing extensors through dorsal compartments to endpoints	+ 15
Discern the peripheral nerves affected by injuries to the upper, lower, medial, lateral, or posterior aspects of the brachial plexus.	Injury upper brachial plexus, describe arm position	atlas diagrams, Charts, drawing brachial plexus, clinical pearl highlights, polling questions	Video tracing brachial plexus from scalenes in neck through axilla and to endpoints in upper extremity	+ 58

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Discern the boundaries, contents, nearby structures, and clinical significance of the anatomical snuffbox and dorsal wrist compartments.	Lac over snuff box into 1,2,3 dorsal compartments, also lac-SBRN	Atlas diagrams, charts, clinical pearl highlights polling questions	Video tracing extensors through dorsal compartments, highlighting snuffbox with contents	+ 17
Predict locations of upper extremity injuries based on physical findings	Injury along lateral chest wall: injury to long thoracic n.	Atlas diagrams, charts, clinical pearl highlights polling questions	Video of axillary boundaries with serratus & latissimus in place, followed from origins to insertions, correlated with function	+ 26
Correlate the attachments, blood supply and innervation of the superficial and deep back muscles with their function.	Injury to latissimus dorsi, vessel injury causing hematoma-thoracodorsal	Atlas diagrams, charts, clinical pearl highlights polling questions	Video of axillary boundaries with serratus & latissimus in place, followed from origins to insertions, correlated with function	+ 16
Describe the boundaries, contents, nearby structures, and clinical significance of the carpal tunnel and Guyon's canal.	Numbness 1,2,3, intact palmar sensation: carpal tunnel syndrome	Atlas diagrams, charts, clinical pearl highlights polling questions	Videos exploring forearm and hand by retracting overlying layers, following nerves, correlating with clinical scenarios	+ 11
Outline the sensory and motor branches of the cervical plexus.	Stab wound neck severing ansa: Motor loss sternothyroid	Atlas diagrams, charts, clinical pearl highlights polling questions	Video exploring neck, retracting skin, platysma, following strap muscles, highlighting function	0
Outline the branches of the external carotid and subclavian arteries and tributaries of the jugular veins.	Thyroidectomy, bleeding, venous blood from middle thyroid vein via internal jugular	Atlas diagrams, charts, clinical pearl highlights polling questions	Video exploring neck, following blood supply to and from thyroid	+ 13
Discern the bony and fascial structures of the hand as well as the spaces and bursa.	Stabbing involving radial bursa, which tendon? FPL.	Atlas diagrams, charts, clinical pearl highlights polling questions	Video following muscles through forearm and wrist, correlating with nerves and bursae	+ 49
Given a nerve lesion in the elbow, forearm, or wrist, predict expected loss of function.	Ruptured biceps with weight training, in add to elbow flexion, also weakening of supination	Atlas diagrams, charts, bone models, clinical pearl highlights polling questions	Video exploring cubital fossa highlighting neurovascular relationships and muscle insertions and functions	+ 23
Integrate the great vessels with adjacent thoracic, neck, and upper extremity anatomy.	First branch off aortic arch: brachiocephalic	Atlas diagrams, charts, clinical pearl highlights polling questions	Videos exploring chest, heart and lungs in place, following great vessels	- 1
Diagram the sympathetic trunks and fiber composition of the white and gray communicans and thoracic splanchnic nerves.	Injury symp chain, white communicans = preganglionic efferent sympathetic	Atlas diagrams, charts, drawing, clinical pearl highlights polling questions	Videos exploring chest, heart and lungs in place, retracting heart and lungs to see sympathetic chain	+ 24
			Average	**+22**

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Introducing the HAPS Physiology Learning Outcomes

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Abstract

The Human Anatomy & Physiology Society (HAPS) has published a set of learning outcomes to be used for curriculum design of a one-semester introductory physiology course. The outcomes are competency-based and are mapped to core concepts and skills students should develop as undergraduates. This paper is an introduction to how the physiology learning outcomes are organized and how they can be used. https://doi.org/10.21692/haps.2023.010

Key words: learning objectives, core concepts, skills, competency-based education, physiology, curriculum design

Introduction

The mission of the Human Anatomy & Physiology Society (HAPS) is to promote excellence in teaching of anatomy and physiology, and, as part of that mission, HAPS members have been working for decades to create standardized guidelines for anatomy and physiology courses. The first set of learning outcomes (LOs) for combined two-semester anatomy and physiology courses was published in 1992, with major revisions in 2010 and 2019. In 2019, HAPS also published a set of LOs for the one-semester undergraduate anatomy class (Human Anatomy & Physiology Society 2019).

The final piece in the development of learning outcomes was to create a set of LOs for the one-semester undergraduate physiology course. Work on the physiology learning outcomes (PLOs) began with appointment of an expert panel in 2019, members of which are the authors of this paper. Completion of the PLOs was scheduled for 2020 but progress came to an abrupt halt with the onset of the COVID-19 pandemic. The panel persevered, however, and it is with great pleasure that we announce the publication of the physiology learning outcomes (Human Anatomy & Physiology Society 2019). The PLOs are published under a Creative Commons CC BY-NC-SA License [https://creativecommons.org/licenses/by-nc-sa/4.0/]. This license is described as "Attribution-NonCommercial-ShareAlike," and means that non-commercial users may adapt, edit, and add to the published PLOs by crediting HAPS and publishing their adaptation under the identical license.

This article explains the philosophy behind creation of the PLOs and includes some helpful hints on how to use the PLOs in your teaching. An abbreviated version of this article, "How to Use the HAPS Physiology Learning Outcomes (PLOs)," is available on the HAPS website (http://www.hapsweb.org) for download. A more detailed description of the development process is being prepared for later publication.

About the PLOs

The underlying philosophy of the PLOs is that we want students to develop a conceptual and long-lasting understanding of how the body works. One of the ways we did this when developing the PLOs was by focusing on core concepts. The core concepts of physiology (Michael et al.

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2017; Michael and McFarland 2020; Modell 2000) are ideas central to the discipline of physiology.

The learning outcomes in the PLO modules also use a competency-based approach, which means that students should be developing skills at the same time they are learning content. We created a list of basic skills we believe every undergraduate life science student needs to acquire, based on the core competency recommendations in the 2011 AAAS *Vision and Change* report as adapted and expanded by Clemmons et al. (2019; 2020). These skills are often synergistic with institutional guidelines and therefore may be helpful in curriculum assessment for accreditation. Individual PLOs are linked, when appropriate, to the six skills that best lend themselves to practice in a physiology course (Table 1).

Process of Science (PS)

PS-1 Draw conclusions based on inference and evidence-based reasoning.

PS-4 Formulate testable hypotheses, make predictions from data, and draw appropriate, evidence-based conclusions.

Quantitative Reasoning (QR)

QR-2 Select and use appropriate mathematical relationships to solve problems.

QR-5 Create and/or interpret graphs and other quantitative representations of physiological processes.

Modeling and Simulation of Physiological Processes, Systems and Diseases (MS)

MS-3 *Use* conceptual models (e.g., diagrams, concept maps, flow charts) and simulations to describe the important components of the model, summarize relationships, make predictions, and refine hypotheses about a physiological process, system, or disease.

MS-4 *Create and revise* conceptual models (e.g., diagrams, concept maps, flow charts) to propose how a physiological process or system works.

Table 1. *Skills mapped to physiology learning outcomes. The full list of skills is posted on the HAPS website:* https://www.hapsweb.org/page/Learning_Outcomes

The PLOs are an exhaustive list of topics that might be included in a one-semester introductory undergraduate physiology course. The PLOs are much more comprehensive and detailed than any student can learn in one term or semester, so instructors using them will need to select the topics and outcomes that are appropriate for their course and their students.

The expert panel followed the accepted principles for writing good learning objectives as laid out by Orr et al. (2022a; 2022b). We have been cognizant of writing learning outcomes that require more than rote memorization and that incorporate higher level Bloom's taxonomy skills (Crowe et al. 2008; Dirks et al. 2014). The PLOs with higher level skills can usually be recognized by verbs such as "compare and contrast" or "predict." Most of the modules end with a section on application of the concepts from the preceding sections.

In deciding what terms to include in a PLO statement, we would often research the current undergraduate human physiology textbooks (for example, Fox and Rompolski 2018; Sherwood 2015; Silverthorn 2019; Widmaier et al. 2018) to see what level of detail is included. Some instructors using the PLOs may be teaching combined anatomy and physiology, and those instructors might want to provide more anatomical detail than is given in the PLOs.

How to use the core concepts

In the last forty years scientific discoveries have grown exponentially, and it is no longer possible for an instructor to cover all of what we know in an introductory survey course, whether it be physiology or general biology. One way to simplify the content of a course is to use the core concepts as the organizing structure.

- First, look at the core concepts in module CC (Core Concepts in Physiology) and decide what big ideas you want to emphasize.
- Ask yourself which concepts you want your students to be able to explain 5 years down the road.
- Then ask: "How can I use those concepts to guide the content for the semester?"
- Choose a few examples of PLOs that reinforce each chosen core concept and emphasize those.

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Students should be introduced to the major core concepts at the start of the course and alerted to the fact that these concepts will appear repeatedly throughout the course. Many of the detailed PLOs presented in Modules CC, A, and B can be introduced as needed at any point in the semester, when related content occurs for the first time.

For example, consider core concept *CC.3.3: Predict how changes in a gradient will affect flow*. There are multiple PLOs across the physiological systems (modules) that map to this core concept, including:

- G.7.5 *Diagram or describe how blood pressure (BP) changes as blood flows from the aorta to the venae cavae.*
- I.2.7 *Graph or describe the change in intrapleural pressure, alveolar pressure, airflow, and lung volume during a normal quiet breathing cycle,* identifying the onset of inspiration, cessation of inspiration, onset of expiration, cessation of expiration, and the timepoints where atmospheric pressure is equal to alveolar pressure.
- J.3.13 *Predict the effect of changes in the resistance of the afferent or efferent arteriole on renal blood flow and glomerular filtration rate (GFR).*

Each module begins with a table showing which core concepts are related to the module. Individual PLOs are mapped to those core concept(s) when relevant. Users can search for PLOs related to each core concept by using the final index document that shows all PLOs that mapped to a concept.

It is important to remember that you will need to be explicit about the core concepts and to point out the examples of core concepts in action each time they occur. Patterns that are obvious to experts often elude novices. By the end of a course, students should be familiar enough with the core concepts that they will recognize them when they encounter them in their later studies. Ultimately, a student may not remember a specific example, but we hope they will remember the core concept.

What is the value of using LOs to help guide your teaching?

The use of learning outcomes (LOs) in higher education has gained traction in the past 15-20 years, and Orr et al. (2022b) have reviewed the evidence supporting writing instructional learning objectives. Using LOs for teaching has an abundance of benefits for both faculty and students. For the instructor, the LOs provide a framework for the design of a course from the chapter level to the unit level and ultimately to the entire course level. Once instructors create a list of LOs, they can then align assessments, both formative and summative, to the LOs (Jalloh et al. 2020). Carefully constructing LOs with action verbs for measurable outcomes makes the creation of assessments follow logically. For students, being provided with LOs and instructed how to use them can increase their confidence and success (Osueke et al. 2019; Thanprasertsuk et al. 2021).

Applying the physiology learning outcomes (PLOs) to your teaching should help inform the organization and rigor of your course as well as reduce your workload. Suggested steps for utilizing the PLOs effectively are based on the principle of backward design (Bowen 2017):

- Select the PLOs you wish to cover in your course, knowing that it will not be suitable to cover all of the PLOs.
- Decide the level of detail that is appropriate for your student population and include the terminology you want students to know in your course version of the PLOs.
- Generate assessments, both formative and summative, that align with each PLO.
- Generate and/or curate teaching resources specific to each PLO.
- Clearly communicate the PLOs and how to use them to students.
- Gather and evaluate the results of the assessments and adjust the instructional strategy if needed.

In subsequent sections of this paper, you will learn more about how to use the PLOs.

Organization of the PLOs

The physiology learning outcomes, like the A&P and anatomy learning outcomes, are organized into modules, but the topics and lettering schemes are different (Table 2).

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Physiology LO Modules	A&P LO Modules	Anatomy LO Modules
Skills summary	A: Body plan & organization	A: Body plan & organization
EC: Entering competencies	B: Homeostasis	C: Chemistry & cell biology
CC: Core concepts in physiology	C: Chemistry & cell biology	D: Histology
A: Cell physiology & membrane processes	D: Histology	E: Integumentary system
B: Cell-cell communication & control systems	E: Integumentary system	F: Skeletal system & articulations
C: Endocrine physiology	F: Skeletal system & articulations	G: Muscular system
D: Cellular neurophysiology	G: Muscular system	H: Nervous system
E: Systems neurophysiology	H: Nervous system	I: General & special senses
F: Muscle physiology	I: General & special senses	J: Endocrine system
G: Cardiovascular physiology	J: Endocrine system	K: Cardiovascular system
H: Blood	K: Cardiovascular system	L: Lymphatic system & immunity
I: Respiratory physiology	L: Lymphatic system & immunity	M: Respiratory system
J: Renal physiology	M: Respiratory System	N: Digestive system
K: Fluid-electrolyte & acid-base homeostasis	N: Digestive system	P: Urinary system
L: Digestive physiology	O: Nutrients & metabolism	R: Reproductive system
M: Metabolism & its control	P: Urinary system	T: Embryology
N: Reproductive physiology	Q: Fluid/electrolytes & acid-base balance	
O: Immune system	R: Reproductive system	
P: Integrated functions & special environments	S: Introduction to heredity	
	T: Embryology	

Table 2. *Comparison of HAPS physiology, anatomy and A&P learning outcomes organization (See: https://www.hapsweb.org/page/Learning_Outcomes)*

The PLOs are organized into 19 modules.

- The first module (Skills summary) lists the skills that students should be acquiring during their undergraduate studies. We identified six skills that lend themselves to practice in a physiology course (Table 1), and individual PLOs are mapped to these skills if appropriate.
- The second module (EC) contains the entering competencies that we hope students have acquired prior to beginning their physiology course. For some student populations that lack pre-requisite courses, it may be necessary to teach or review some introductory biology or general chemistry concepts at the beginning of the physiology course.
- The third module (CC) focuses on the core concepts of physiology, those fundamental themes that appear repeatedly in different body systems. Each subsequent module begins with a table showing which core concepts from the CC list are related to that module. In addition, individual PLOs are mapped to the underlying core concept(s) when relevant.
- The next 15 modules (A-O) cover the organ systems or related concepts such as metabolism, cell physiology, and communication mechanisms. The final module (P) includes integrated functions and physiology of special environments.

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For a graphical overview of module organization, please see the infographic in Figure 1. Each module contains the following sections:

Introduction

- Introduction to the module: This section has a brief overview of the module that explains what is and is not included. Terminology notes are also included here.
- Core concepts from Module CC, with the annotation "Students need to understand and be able to apply these core concepts in order to be successful in this module."
- Skills: a key to the skills that can be practiced with the PLOs in the module, with PLOs matched to the appropriate skills.

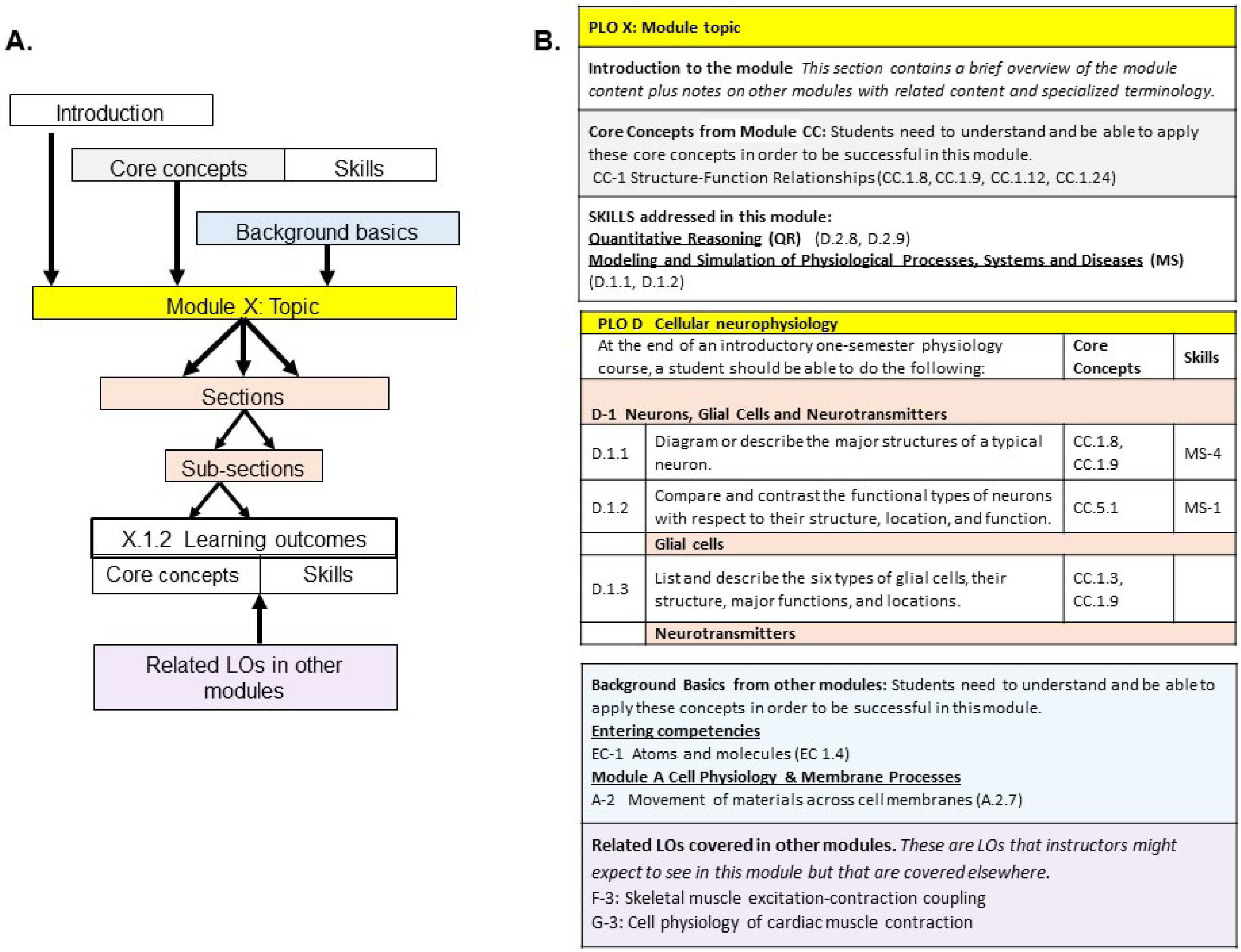

Figure 1. *Infographic showing the elements and organization of each module. (A) A map showing the elements that can be found in each module. (B) An abbreviated module showing how the different elements appear within the module.*

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Learning Outcomes for the Module

The physiology learning outcomes (PLOs) are organized into numbered sections, with the number preceded by the module letter. For example: Module A contains section A-2 Movement across membranes. PLOs within that section are numbered sequentially: A.2.1, A.2.2, A.2.3, etc. Sub-sections are indicated with colored headers and continue the section numbering sequence.

- Advanced learning outcomes are indicated with an asterisk, as in D.1.12*.
    - Advanced PLOs address higher level skills or additional detail that may appear in some physiology texts but that may not be appropriate for all introductory physiology classes.
- The two right-hand columns of the table indicate core concepts and skills related to specific learning outcomes.

Background Basics and Related PLOs

- Background Basics from other modules: These are lists of content that students should have mastered before attempting this module.
- Related PLOs covered in other modules. These are learning outcomes that instructors might expect to see in this module but that are covered elsewhere. For example, PLOs about blood types are in Module H *Blood*, where most physiology courses teach them, rather than in Module O *Immune System*. Each topic appears only once in the learning outcomes.

Terminology

The expert panel recognizes that there is considerable variability in the level of detail taught in introductory physiology courses. Our solution is to create broad learning outcomes, such as *K.1.2 Label the structures in a cross-sectional diagram of a kidney*, using a parenthetical (e.g., ...) to provide examples of some of the structures that an instructor might want students to label. The list of terms following an *e.g.,* is not all-inclusive, and the PLOs are not trying to be prescriptive about what should be taught. The decision about which details to teach is up to individual instructors so that they can adapt PLOs to fit their student populations.

Terminology conventions in this document

- (e.g., ...) in a PLO means *for example, ...*
- (i.e., ...) means *in other words, ...*
- When multiple terms can be used to refer to a single physiological process or anatomical structure, common alternatives are included in parentheses after our preferred term.
- We attempted to replace eponyms and use anatomical terminology as given in the *Terminologia Anatomica* 2e (FIPAT 2019), but we recognize that certain terms are entrenched in the clinical literature and used daily in healthcare. The PLOs use the preferred physiological term, followed by historical alternative terms in parentheses.
- *Draw* and *diagram* are considered to mean the same thing: a graphical representation that may be literal or abstract, such as a concept map. We chose to use *Diagram* as our preferred term in these outcomes.
- Numerous PLOs begin with the words "*Diagram or describe*." For these PLOs, the preferred student action is to draw or map a visual representation of the concept, but for students who have difficulty creating visual representations, the alternative action is to use words to describe the topic.

Inclusive language

The expert panel has been cognizant of trying to use inclusive language whenever possible. We have questioned whether the word "normal" in a PLO can be replaced with an alternative such as "healthy" or "typical," to avoid the implication that if something is not normal, it must be abnormal.

Sex and gender

The HAPS Physiology LOs address biological aspects of sex and reproductive physiology in Module N, and we attempt to use a broader, more accurate, and inclusive approach to teaching this topic. All students should be aware of the biological variability that can occur during development and that creates diversity in human physiology and anatomy. We recognize that because of time constraints, most one-semester introductory physiology courses do not have time to go into the complex biopsychosocial topic of gender, but we feel that our students should be able to distinguish between sex and gender, and we have included one learning outcome (N.1.1) that asks students to do this.

Summary

The PLO expert panel (the authors of this paper) hope that you find the physiology learning outcomes and associated documents useful. Instructors who were looking for a short list of topics that are essential for a one-semester course will be disappointed by the extensive nature of the modules. However, our goal was to represent the broad range of topics encompassed in physiology courses taught to varied student populations (Wehrwein et al. 2020). The closest we can come to providing a single list is Module CC, the core concepts of physiology. These are the "big ideas" of physiology that should be included in every physiology course, no matter which organ systems are taught.

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We close with a short list of reminders for adopters of the PLOs.

- The entire PLO document is far more comprehensive and detailed than any student can learn in one term or semester. Instructors need to select the topics and outcomes that are appropriate for their course and their students.
- Users will need to decide the terminology appropriate for their students and edit the PLOs accordingly.
- Instructor-users should share their chosen and edited PLOs with their students to help guide student study.
- All assessments in the class and class activities should align with the chosen PLOs.

Documents such as the PLO are works-in-progress and subject to periodic revision. We welcome your feedback and suggestions.

About the Authors

The authors of this paper are members of the expert panel that wrote the HAPS PLOs. The panel was assembled from respondents to a HAPS call for volunteers in summer 2019. Members were selected to represent the broad range of institutions found in the HAPS membership. Patrick Cafferty, PhD, is Director of Undergraduate Studies and an associate teaching professor in the Department of Biology at Emory University in Atlanta, Georgia where he teaches courses in introductory biology, human physiology, and developmental neurobiology. He also serves as Southern Regional Director (2021-2023) for the Human Anatomy and Physiology Society (HAPS). Janet Casagrand, PhD, is an associate teaching professor in the Integrative Physiology Department at the University of Colorado Boulder, where she teaches human physiology, physiology lab, endocrinology and neurophysiology. She is also the Anatomy and Physiology Exam Program Lead for HAPS. Elizabeth Co, PhD, is a senior lecturer at Boston University, where she teaches Human Anatomy, Human Physiology, and the Physiology of Sex and Reproduction. She is the author of *Anatomy & Physiology* 1/e (Cengage). Meg Flemming, MS, Vet Phys. is a professor in the Biology Department at Austin Community College where she has been teaching anatomy and physiology for 22 years. Meg has contributed to the teaching ancillaries for Silverthorn's *Human Physiology: An Integrated Approach*, 2013 and 2016. She has been a member of HAPS since 2010. Jenny McFarland, PhD, is emeritus faculty and former department chair of the Biology Department at Edmonds College where she taught human anatomy & physiology and introductory biology courses for more than 20 years. Her research in biology education focuses on core concepts for undergraduate physiology. Valerie O'Loughlin, PhD, is a professor of anatomy, cell biology & physiology at Indiana University School of Medicine - Bloomington, where she teaches human anatomy to undergraduates, gross anatomy to medical students, and health sciences pedagogy to graduate students. She is the HAPS Anatomy Exam Program Lead and a HAPS president emeritus. She is co-author of *Human Anatomy 6e* (McGraw Hill Education) as well as co-author of *Human Anatomy & Physiology: An Integrated Approach* (McGraw Hill Education). Derek Scott, PhD, holds the Chair of Physiology & Pharmacology Education at the University of Aberdeen, UK. He teaches physiology to a variety of science and healthcare students at undergraduate and postgraduate levels. Derek was previously the Education & Teaching Theme Lead for the UK Physiological Society. Dee Silverthorn, PhD, is a Distinguished Teaching Professor of Physiology emerita at the University of Texas at Austin, where she taught physiology to students ranging from non-science majors to medical students for more than 30 years. She is the HAPS Physiology Exam Program Lead and a HAPS president emeritus. She is also the author of *Human Physiology: An Integrated Approach 8/e* (Pearson). Nanette J. Tomicek, PhD, is Director of Anatomy and Physiology Courses and an assistant professor in the College of Life Sciences at Thomas Jefferson University in Philadelphia. She co-authors *Physiology Laboratory Manual. 5/e (Macmillan Learning)* and teaches introductory anatomy and physiology, human physiology, and the biology of sex. She also serves as Eastern Regional Director (2020-2024) for HAPS.

Acknowledgements

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On Heat and Water Exchange in the Airways

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Abstract

The air conditioning function of the airways plays a key role in the structural and functional integrity of the respiratory tract. Faced with different environmental conditions of temperature and relative humidity, the inspired air conditioning mechanism adapts to deliver air at body temperature and 100% relative humidity to the lungs. In addition, during the expiratory process, the airways recover some heat and water, sparing the body from excessive losses. Disruption of this mechanism quickly leads to serious and well-known symptoms. However, despite the importance of the air conditioning process, little attention is paid to this topic in physiology textbooks, treating it punctually and superficially. Here, I present an alternative and complementary material to the understanding of the mechanisms underlying the exchange of heat and water in the airways. The principles of these mechanisms encompass physical processes of heat and water exchange, the special geometry of the airways that defines the airflow profile, and the structure of the airway wall that provides heat and water. The theme was developed and delivered through a constructivist sequence, starting from simpler ideas, and progressively moving to more complex ideas. I deliver this material in my Respiratory Physiology course. I believe this strategy gradually builds up the concepts and easily engages students in a comprehensive sequence, allowing them to visualize heat and water exchange mechanisms. I hope this material can be useful for instructors and students interested in this topic. https://doi.org/10.21692/haps.2023.002

Key words: air conditioning function, heat transfer, air humidification, inspiratory process, expiratory process

Introduction

Atmospheric air, which contains essential O_2 for aerobic life, is generally cooler and drier than the lining of the respiratory tract (Jackson 1996). This is an inevitable and constantly challenging scenario since the extensive and delicate epithelial surface of the lower airways is quite sensitive to thermal injury and dehydration. An essential thermal and water homeostatic adjustment is performed by the upper airways, i.e., the inspired air is conditioned to BTPS (body temperature and pressure, saturated with water vapor) conditions before reaching the lower airways, thus maintaining the integrity of structural and functional of the respiratory tract (Wilkes 2001).

It is also important to note that atmospheric air contains a mixture of suspended particles such as dust, pollen, soot, and smoke, as well as fungi, bacteria, and viruses. These inhaled foreign particles are potentially harmful and infectious for the alveolar space, which, in contrast, must always be in quasi-aseptic conditions (Dickson and Huffnagle 2015). An essential clearance is performed by the first line of defense of the respiratory tract, the mucociliary clearance mechanism, which traps the particulate matter present in the inspired air in its mucous component and removes it to the pharynx by the ciliary beating, maintaining the health of the airways (Bustamante-Marin and Ostrowski 2017). However, the proper functioning of mucociliary transport is closely related to the thermal and water conditioning of the inspired air. Inadequate air conditioning can quickly lead to impairment of the mucociliary mechanism, triggering profound changes in airway functions (Khosravi et al. 2021).

In addition to these crucial and vital protective functions, the inspired air conditioning mechanism must also be considered in the body's water and caloric balance (Bilgili et al. 2019). As the heat and water supplied to the inspired air during inspiration are not totally recovered during expiration, there is a net loss of heat and water through respiration (Walker and Wells 1961; Jackson 1995).

Despite the importance of the physiological mechanism and clinical interest, the fundamentals of heat and water exchange through the respiratory tract have been a subject of limited coverage in conventional textbooks. Here, we intend to provide complementary material with a phenomenological and quantitative view of this topic. The starting point will be the thermal agitation of the constituent particles of the matter.

The motion of the molecules

Here, the particles that will be considered are molecules and it can be said that their *kinetic energy* is the driving force for both the heating and humidification processes of the inspired air. According to the kinetic theory, above the

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temperature of absolute zero, all the constituent particles of matter have kinetic energy associated with the movements of translation, vibration, and rotation. Particularly, the theorem of equipartition of energy states that molecules in thermal equilibrium have the same average translational kinetic energy (E_k) (Tinoco et al. 1995), which is related to temperature by:

$$E_k = \frac{3}{2} R * T \quad (1)$$

where *R* (8,3 J*K^{-1}*mol^{-1}) is the gas constant and *T* is the temperature in kelvin (K).

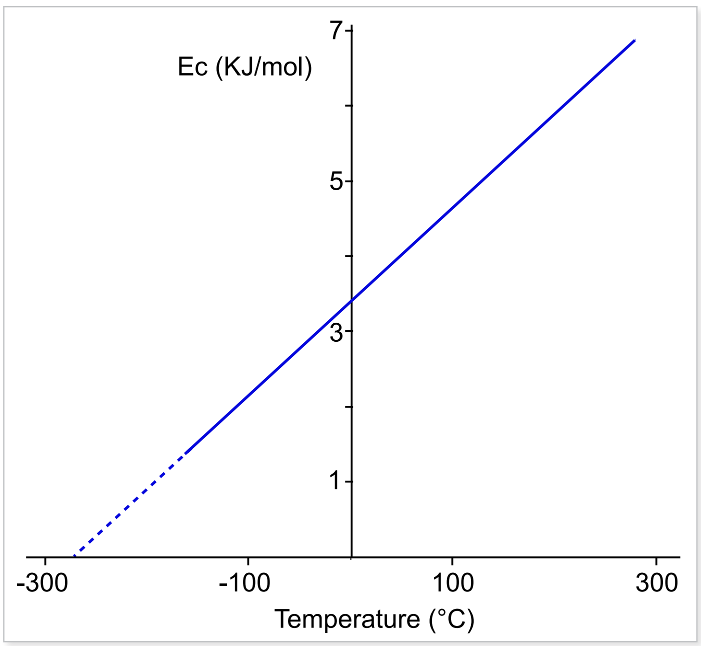

Figure 1. *The linear relationship between the kinetic energy of the molecule kinetic energy and temperature. At the temperature of -273 ºC the molecules do not translate. Graphic generated in GeoGebra Software (GeoGebra, n.d.).*

Figure 1, which graphically depicts equation 1 when *T* is converted into degrees Celsius, shows that to stop the movement of molecules the temperature must be very low (-273°C), which makes us think that at body temperature (37°C) the kinetic energy of the molecules is very large. Thinking about the fact that any moving body can do some work when it collides with another, or even that its motion can transport something from one place to another, the concept that particles move incessantly when *T* is above absolute zero can give us an idea of how important the thermal agitation of particles can be for many processes in nature, including the heating and humidification of inspired air. However, equation 1 means the *average* E_k of the molecules; therefore, there are molecules at different speeds that are constantly and randomly colliding with each other. These collisions are perfectly elastic; while one molecule gains energy, the other proportionally lose it (Tinoco et al. 1995). In other words, collisions *transfer* kinetic energy from one molecule to another. The distribution of the speeds of the molecules of a gas at a given temperature is described by the Maxwell-Boltzmann distribution (Halliday et al. 2013):

$$f(v) = 4\pi v^2 \left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} e^{-\frac{mv^2}{2kT}} \quad (2)$$

where *k* is the Boltzmann constant (1,38 * 10^{-23} J*K^{-1}) and *v* and *m* are the speeds and molecular mass, respectively. Note that the mass of the molecule and the temperature control the distribution. Although in the liquid state the spatial translation of water molecules is strongly influenced by intermolecular forces, the distribution of speeds is similar to the one described by the Maxwell-Boltzmann distribution for gases (Denny 1993). Let us see the distribution of the speeds of water molecules (*m* = 18 g*mol^{-1}) at 37°C (310 K) plotted on a graph as in figure 2 with molecular speeds on the x-axis and the relative frequency density of particles on the y-axis.

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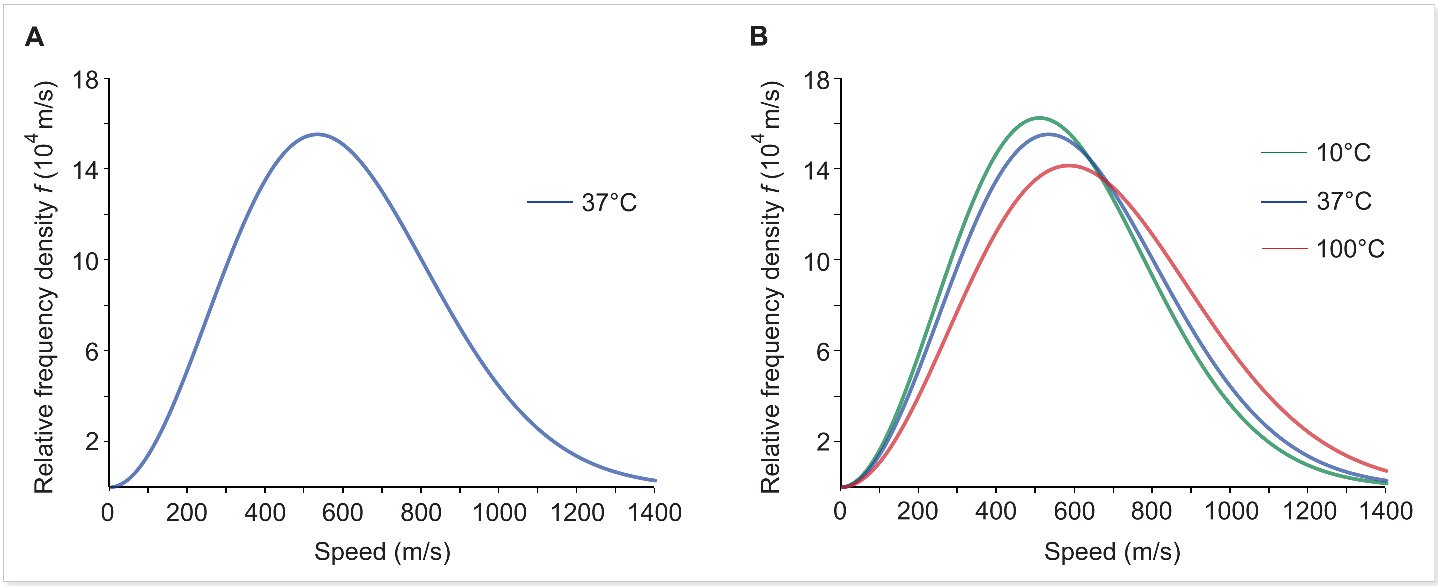

Figure 2. *Maxwell-Boltzmann distribution. A – Speed distribution of the molecules at 37ºC. B – Speed distribution of the molecules at three different temperatures. Graphic generated in GeoGebra Software (GeoGebra, n.d.).*

Note in figure 2A that the most probable speed, i.e., the maximum value on the distribution plot, is around 520 m*s^{-1} or, equivalently, more than 1.800 Km*h^{-1}, a supersonic velocity. Also, note in the distribution that there are molecules with lower speeds while others translate space with even higher speeds. This exuberantly high kinetic can immediately give us an idea of the dynamics of many processes in nature, including heating and humidification of inspired air.

Temperature

Let us go back to equation 1 and take *T* as the dependent variable so that we can define the temperature:

$$T = \frac{2}{3R} * E_k \qquad (3)$$

In this way, it can be said that the average kinetic energy defines *T*. In other words, *T* is a measure of the thermal agitation of the particles (Halliday et al. 2013); if the thermal movement (speed) increases, the temperature increases proportionally. Figure 2B shows this relationship through the Maxwell-Boltzmann distribution; at higher *T*, the most probable speed of the molecules is shifted to a higher value and more molecules translate at higher speeds. Thus, an increase in the kinetic energy of the molecules leads to an increase in temperature, and ultimately what increases the kinetic energy of the molecules is the input of thermal energy or heat (*Q*).

Heat Transfer

From the above discussion, to change the thermal agitation of the particles and therefore the temperature (warming), heat transfer is required. *The specific heat capacity* (*c*), a physical property of matter defined as the amount of heat required to change the temperature of a mass unit of a given substance by 1 °C, is of crucial importance for heat exchange and is given by:

$$c = \frac{1}{m * \Delta T} * Q \qquad (4)$$

In other words, it can be said that *c* defines the ease with which the temperature of a given substance can be changed, or, still, *c* defines how much heat must be supplied or withdrawn from a given amount of a substance to change its temperature at a certain value. Therefore, we can rewrite equation 4 as:

$$Q = c * m * \Delta T \qquad (5)$$

This kind of heat is denominated sensible heat (Q_S). As a comparative example for our purpose, *c* of water (4182 J*kg^{-1}*ºC^{-1}) is much larger than that of air (1,005 J*kg^{-1}*ºC^{-1}), meaning it is necessary to transfer much more heat to heat or cool water than air.

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Heat transfer takes place in four different ways, namely by radiation, conduction, convection, and phase transitions. At room temperature, the heat exchange rate by thermal radiation is relatively low (Walker and Wells 1961) and will not be considered here.

Heat conduction is the transfer of heat by direct contact of atoms and molecules within an object or between two objects in contact. It is proportional to the temperature gradient (and area), which means that as long as there is a temperature difference, heat transfer will occur. A cup at room temperature (25°C) can be useful for conceptualizing heat conduction. The particles that form the wall of the cup are trapped in a lattice structure, but they are not stationary, they have kinetic energy associated with a vibrating motion around a fixed position. The vibrating particles collide and transfer kinetic energy between them but, in thermal equilibrium, the average kinetic energy is the same for all particles. Filling the cup with hot water (100ºC) creates a thermal imbalance; heat will be transferred spontaneously from the water to the wall of the cup and then to the air until thermal equilibrium is restored. The water molecules, with higher average speed, collide elastically with the particles of the inner surface of the cup wall, transferring kinetic energy to them. The average kinetic energy of the water molecules starts to decrease and therefore the water starts to cool, while the average kinetic energy of the particles on the cup wall starts to increase and therefore starts to heat up. Thus, heat is *conducted* from the water to the wall of the cup. Likewise, as the particles on the inner face of the cup gain heat, they collide more vigorously with their neighbors, also transferring kinetic energy to them, so that heat is *conducted* through the wall of the cup. Finally, the outer surface of the cup wall transfers kinetic energy to the air molecules, dissipating heat and reestablishing thermal equilibrium.

Heat convection is the transfer of heat that occurs particularly in a moving gas or liquid phase. Under normal conditions, both gas and liquid are poor conductors of heat, but they can transfer heat easily by convection. There are two kinds of heat transfer convection. *Natural convection* is considered in figure 3, which shows a glass container placed upside down on a metal block maintained at 100°C. Let us consider that the objective of this experiment is to measure the heat transfer rate, and therefore the time required to heat the air inside the container to a temperature of 100°C. In this condition, as soon as the glass container is placed on the metal block (figure 3A), the air molecules inside the container gain kinetic energy as they collide with the constituent particles of the block surface; heat begins to be transferred by conduction from the metal block to the air inside the container. Since the heat conduction process depends on the temperature difference, it is evident that if the air closest to the block being heated is replaced by cold air, the heat conduction process between the block and the air is optimized as the temperature gradient is kept as high as possible. Figure 3B illustrates that a mass flow replacing hot air with cold air at the block-air interface occurs under the influence of gravity. The warmer, less dense air at the bottom of the container rises due to the buoyancy process, while the cooler, denser air at the top sinks, forming a convection current, which carries heat away from the block-air interface. In this way, the convection heat keeps the heat conduction between the metal block and the air as high as possible, and the air inside the container is heated up to 100°C faster than if there were no convection current.

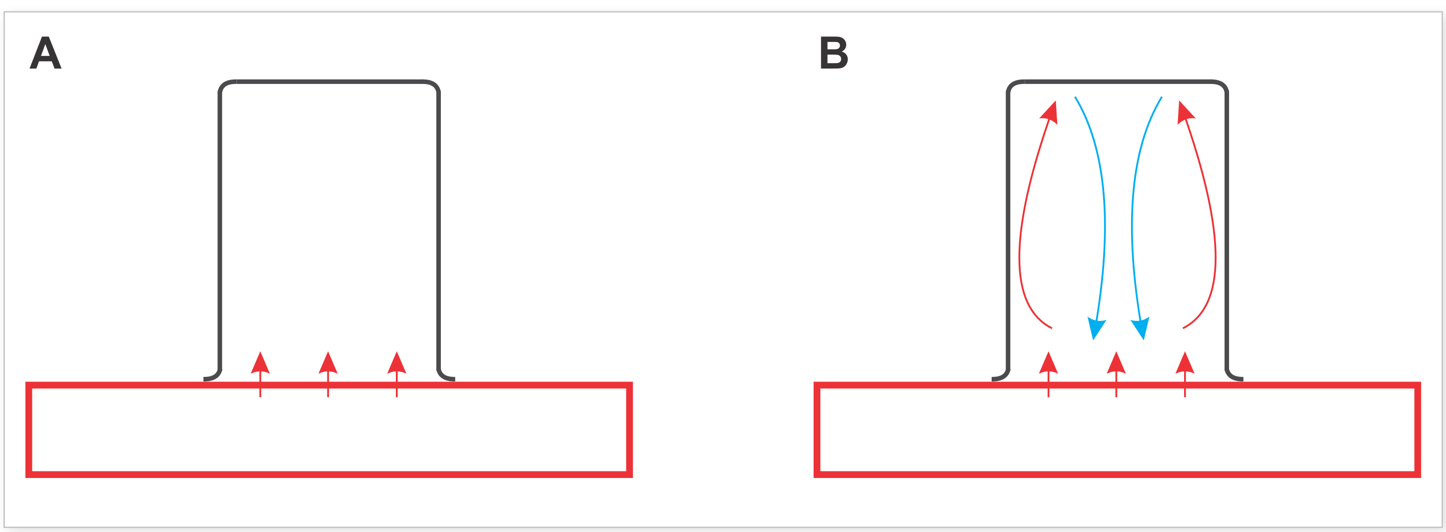

Figure 3. *Heat transfer. A – Conduction heat transfer (red arrows) from a hot metal block (red rectangle) to the air inside of the container. B – Natural convection heat transfer. The buoyancy process creates convection currents, which spread heat through the air mass. Hot air is constantly replaced by cooler air at the block-air interface, keeping the temperature gradient as high as possible for heat conduction from the block to the air, accelerating thermal equilibrium.*

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Forced convection increases the heat transfer rate. It occurs when the movement of the fluid carrying heat away results from mechanical pumping or pressure difference. Let us consider the system represented in figure 4; a pipe passing through the middle of a metal block previously heated to 100°C. A fan installs a flow of air through the pipe. Assuming the flow is laminar, a longitudinal stream carries the heat away. In other words, heat is transferred from the metal block to the wall of the pipe and then to the air inside the pipe by conduction and the convective current carries the heat out of the pipe. The convective current forced by the fan constantly replaces the hot air with the cold air keeping the temperature difference between the block and the air as high as possible and therefore also the heat conduction. However, as the flow regime is laminar, as represented by parallel dashed lines in figure 4A, the air flowing in the center of the pipe does not come into contact with the wall so that it can be heated by conduction. In addition, as the air flows quickly, there is not enough time for the entire mass of air in the stream to be heated properly by conduction, so this system is more efficient in cooling the block by conduction than in heating the mass of air in the stream. Figure 4B illustrates an adaptation of the system to better heat the air mass in the forced convective current passing through the pipe. The radial projections of the pipe wall provide two important effects. First, they increase the contact surface available for the heat conduction process. Second, due to inertial forces, they change the airflow regime from laminar to turbulent. Turbulence mixes the flowing air in the same way that convective current does in natural convection, allowing the entire mass of air to come into contact with the conduction heat exchanger surface. In this way, the heating of the air mass is optimized, and, depending on the geometric characteristics of the pipe, the entire mass of air leaving the pipe may be in thermal equilibrium with the block (figure 4B).

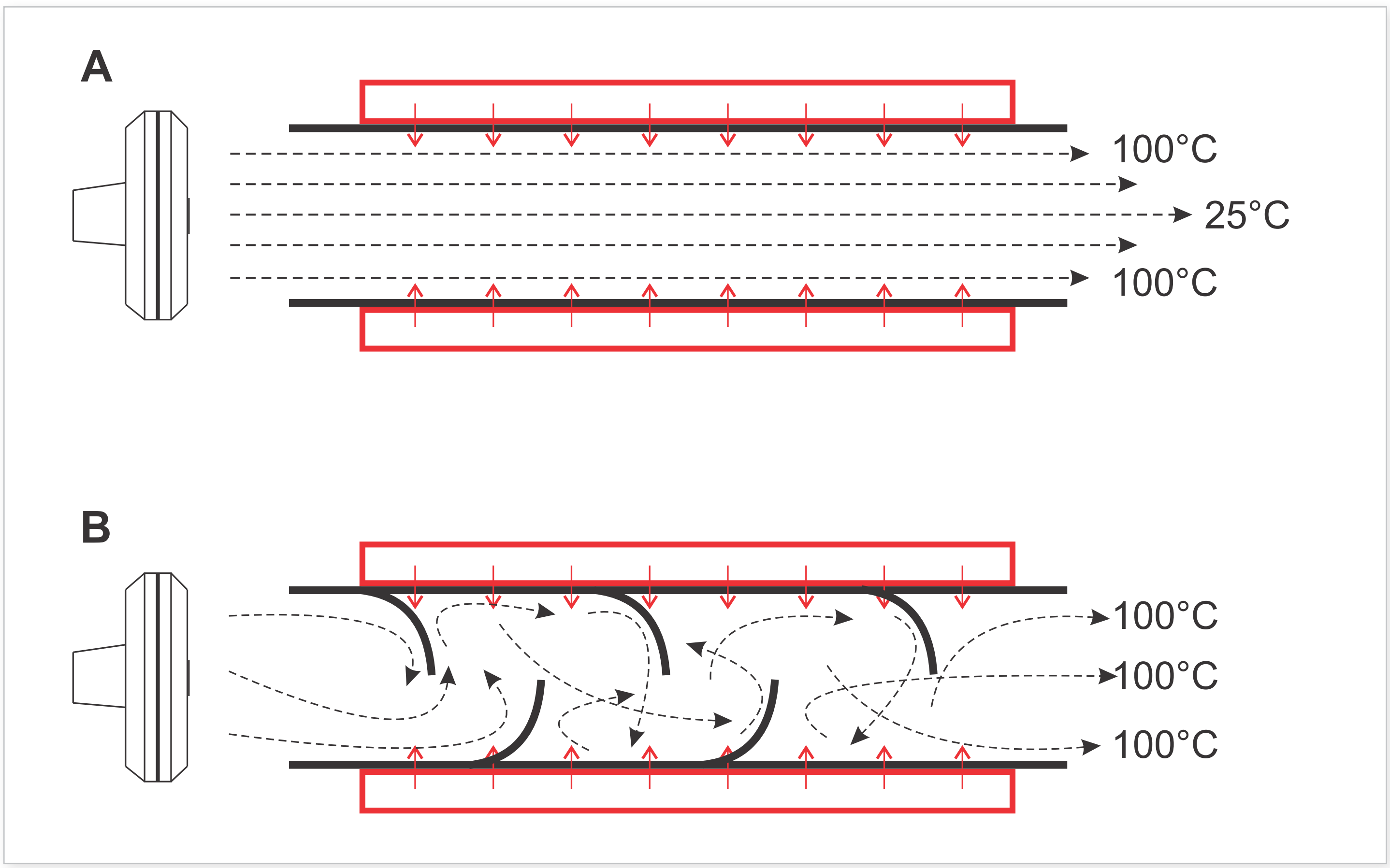

Figure 4. *Forced convection heat transfer. Firstly, the heat is transferred by conduction (red arrows) from the hot metal block (red rectangles) to the air stream (dotted lines) through the pipe. A – Under a laminar flow regime, not all air in the stream comes into contact with the heat exchanger surface. Central and faster air stream does not thermally balance with the block. B – The special geometry of the pipe increases the surface area of heat exchange and develops turbulent flow. Convective currents bring the entire air mass into contact with the exchange surface, optimizing the heating of the air stream.*

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Phase transition is when a substance changes from one state to another. For our purposes, what matters are the *evaporation* and *condensation* of water, which, in addition to being a form of heat transfer, is also responsible for saturating the air in the airways with water vapor. Let us consider a container of water placed in a dry air environment at room temperature. It is intuitive that the body of water in the container slowly dries up, that is, the water evaporates. It is worth noting that in the liquid state each water molecule makes electrostatic contacts, i.e., hydrogen bonds, with as many as four neighboring water molecules (Nelson and Cox 2017), meaning that it is necessary to break the bonds to escape from the liquid phase. The molecules capable of achieving this condition of individuality are those found on the surface of the water body (water-air interface) and with higher kinetic energies, that is, those located to the right in the Maxwell-Boltzmann distribution (figure 2). Following the reasoning of Denny (1993), the average velocity (*vrms* - root mean squared speed) of water molecules at 100°C is sufficient to allow escape, which can be calculated by:

$$vrms = \sqrt{\frac{3 * R * T}{m}} \quad (6)$$

which gives the *vrms* of 719 $m*s^{-1}$. Thus, molecules with a speed close to 719 $m*s^{-1}$ (~ 2,590 $km*h^{-1}$) located at the air-water interface would be those most likely to absorb extra energy by colliding with their neighbors, rearrange their molecular structures, break hydrogen bonds, and escape into the gas phase as individual molecules. They *evaporate* and then exert partial pressure like a gas, i.e., the vapor pressure of water. This is an endothermic process; the energy absorbed to break the hydrogen bonds is stored within the internal structure of the molecule that passes into the gas phase, being associated with internal potential energy rather than with translational kinetic energy. In this way, during evaporation, the body of water in the container cools, but the air does not heat up; it is only *humidified*. The heat transported and "hidden" within the water molecule that evaporates is called latent heat (Q_L) and is given by:

$$Q_L = m * L \quad (7)$$

where *L* is the specific heat of water evaporation (in $kJ*g^{-1}$).

Condensation is the reverse process of evaporation; it is an exothermic reaction. Let us consider a container of water covered with a glass dome and, for simplicity, disregard changes in air pressure above the body of water. As the surface water molecules evaporate the water content in the air increases. Of course, the speed distribution of the water molecules in the air follows the Maxwell-Boltzmann distribution (figure 2). It is intuitive to assume that water molecules in the gaseous state, moving randomly, also start to collide with the surface of the water body. It is also intuitive to infer that those that collide with the water body with speeds lower than 719 $m*s^{-1}$ have a high probability of reestablishing hydrogen bonds, being then recaptured by the liquid phase: they *condensate*. During the condensation process, latent heat is released, heating the water body but not cooling the air. As evaporation proceeds, the rate of condensation increases until eventually, both processes become equal, and the system is in equilibrium. At this point, the air above the water body is saturated with water vapor (100% relative humidity). However, note in Figure 2B that the higher the temperature, the greater the number (probability) of molecules with velocities above 719 $m*s^{-1}$. When these molecules collide with the body of water, they are very likely to overcome the forces of attraction and bounce back into the gas phase. Thus, we can conclude that the higher the temperature of the air, the greater the number of water molecules it can contain and, therefore, the greater the water vapor pressure. Let us quantitatively characterize these variables.

The relationship between the saturated vapor pressure (*P*) and temperature can be described by the Antoine vapor pressure correlation (Rodgers and Hill 1978), which is given by:

$$P = 10^{A - \frac{B}{C+T}} \quad (8)$$

where A, B, and C are Antoine's constants, which assume values of 8.07, 1730, and 233, respectively, for *P* in mmHg and *T* in °C.

The content of water in the air (grams of water per m^{-3} of air), which generates the vapor pressure, as a function of temperature is defined as absolute air humidity (*AH*) and is given by:

$$AH = \frac{RVP * MW}{R * T} \quad (9)$$

where *RVP* is the relative vapor pressure and *MW* is mass weight. *RVP* is the relative humidity of the air (measured by a hygrometer) times *P*. The nonlinear relationships predicted by the Antoine correlation between water vapor pressure and absolute humidity as a function of temperature for air fully saturated with water vapor are shown in figure 5. At all points on the curve, the evaporation and condensation rates are equal.

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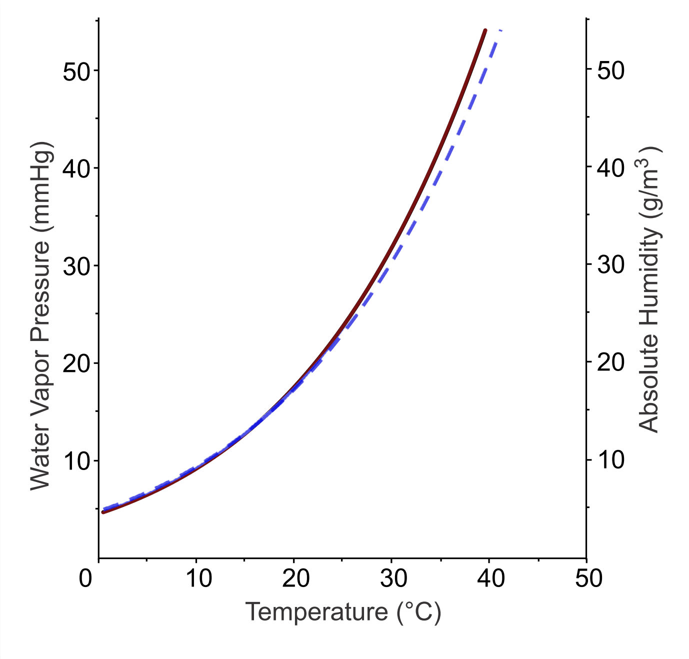

Figure 5. *The nonlinear relationships between water vapor pressure (solid line) and absolute humidity (dashed line) as a function of temperature for air fully saturated with water vapor. Graphic generated in GeoGebra Software (GeoGebra, n.d.).*

The Exchange Structure

The upper airway wall is designed to exchange heat and water efficiently with air. Despite the short time of the inspiratory process, normally the cool and dry inspired air becomes fully conditioned just below the carina (Hedley and Allt-Graham 1994), the anatomical point termed the isothermic saturation boundary. Roughly speaking, this amazing speed of exchange is accounted for by three important elements: the aerodynamic properties of the airways, the supply of heat and moisture from the mucosa, and, ultimately, the supply of blood as the primary source of heat and water.

The portal of entry, the nasal cavity, is where most of the conditioning of the inspired air takes place (Naclerio et al. 2007). Its geometric features provide an adequate airflow regime, area, and temperature gradient that maximize exchanges. The aerodynamic design appropriately divides the airflow into specific high-shear zones, optimizing heat and water exchange with the nasal mucosa. The turbinates, normally in a number of three, are scroll-like projections from the lateral nasal wall (Sahin-Yilmaz and Naclerio 2011) that, together with the nasal septum, increase the total mucosal surface area available for heat conduction and water evaporation. The turbinates make the nasal cavity a very narrow and highly curved passage in both anteroposterior and lateromedial directions, inducing, like the radial projections in figure 4B, strong turbulence in the air stream by inertial forces. The turbulent flow acts as a convective current, which mixes the inspired air allowing most of it to come into contact with the mucosal surface that exchanges heat and water by conduction. In other words, the convective current forced by the pressure difference during inspiration (and expiration) and the convective current generated by turbulent flow transfer or dissipate heat in the gas phase while heat conduction and evaporation exchange heat and water between the mucosa and the gas phase. Other major turbulences are generated by the constriction at the level of the vocal folds and by the high Reynolds number along the trachea, also contributing to humidifying the inspired air and equalizing its temperature with that of the mucosa (Dekker 1961; Olson et al. 1972).

Ultimately, heat and water to condition inspired air are provided by blood flow. As a corollary, the airway wall is supplied with an extensive network of blood vessels. Particularly, the nasal cavity, the main site of exchange, contains a specialized organization of arteriovenous anastomoses that create favorable conditions to deliver adequate amounts of heat and water (Sahin-Yilmaz and Naclerio 2011). The heat flow between the blood and the mucosa follows the temperature gradient by conduction. Water, in turn, leaves the blood vessels according to Starling forces and flows to the mucosa either via transcellular (aquaporins) or paracellular route following the osmotic gradient (Frizzell and Hanrahan 2012), as well as through the secretion of the submucosal glands (Haut et al. 2021). The osmotic gradient results from the transepithelial flow of anions and cations through a set of channels and transporters in the apical and basolateral membranes of epithelial cells. The key osmolyte is chloride, which enters through the basolateral membrane driven mainly via sodium cotransport and leaves through the apical membrane by anionic conductance (Frizzell and Hanrahan 2012). Chloride in the lumen establishes an electrical driving force to move sodium into the luminal compartment via the paracellular pathway. Then, water flows into the lumen driven by the osmotic force generated by the chloride and sodium.

Airways as a Countercurrent Heat and Water Exchanging System

Considering what has been discussed so far, we believe it is possible to directly address the scope of this work, the exchange of heat and water in the upper airways. Air temperature and humidity can vary greatly depending on weather conditions. However, as already pointed out, before reaching the alveoli, the normally cooler and drier inspired air is conditioned to body temperature (37°C) and fully saturated with water vapor (100% relative humidity, with a water content of 43.8 g*m^{-3} - figure 5). In addition, during expiration the airways can recover some of the heat and water, acting as a countercurrent mechanism to prevent further heat and water loss through breathing (Jackson 1996). At room temperature, expired air is at 32°C (Jackson 1996; Khosravi et al. 2021) and, although saturated with water

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vapor, contains only 33.74 g*m^{-3} (figure 5). The temperature of the nasal mucosa plays a key role in this dual role of the airways of providing heat and water during inspiration and conserving them during expiration. Despite being extensive, the vascularization of the nasal cavity is not able to maintain the mucosa at body temperature during inspiration (Haut et al. 2021), so it oscillates around an average value during each respiratory cycle, providing a temperature gradient both with the inspired air as with the expired air. The temperature gradient between the mucosa and the air is present along the airways but is greater in the nasal cavity and progressively decreases to zero at the isothermic saturation boundary. Generally, cooler, drier-inspired air comes into contact with the mucosa and is warmed to body temperature, cooling the mucosa. During expiration, the mucosa that has not yet reached body temperature cools the heated air from the alveoli at the same time as it is warmed. Let us take a closer look at this mechanism considering breathing at an ambient temperature of 20°C and a relative humidity of 50%. We will follow figure 6, which shows both the relationship between relative water vapor pressure and temperature (solid lines) and absolute humidity and temperature (dotted lines) in two situations, namely, 100% (blue lines) and 50% (red lines) relative humidity. During the respiratory cycle, the upper airway mucosa conditions the air by shifting the inspired current from points A/A′ to B/B′ and exhaling air from B/B′ to C/C′.

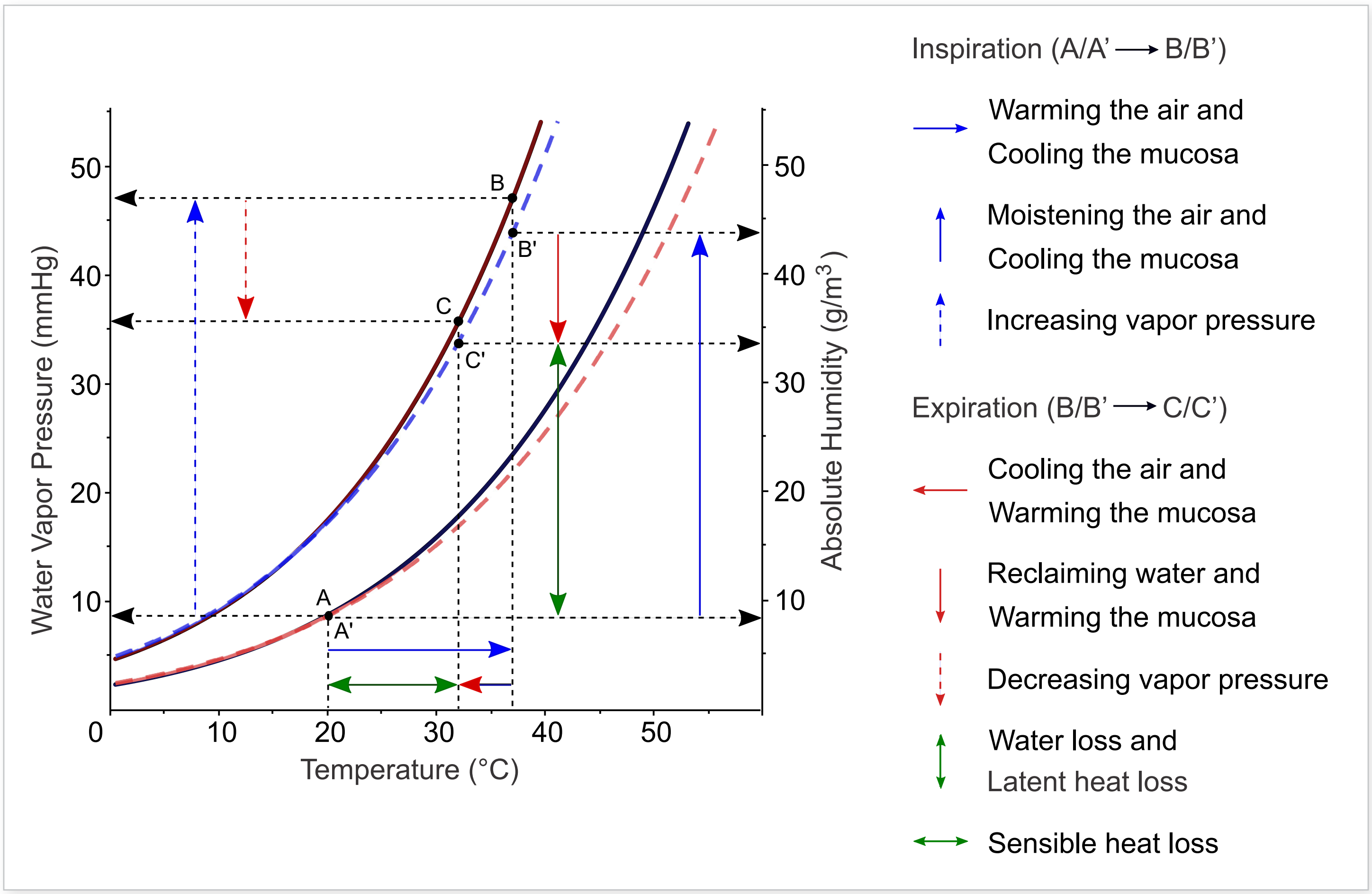

Figure 6. *The nonlinear relationships between water vapor pressure (solid lines) and absolute humidity (dashed lines) as a function of air temperature under two saturation conditions, at 100% (blue lines) and 50% relative humidity (red lines). At an ambient temperature of 20°C and 50% relative humidity, the air is at points A and A′. During inspiration, the temperature, the water content, and, consequently, the water vapor pressure of the air gradually increase. Just below the carina, the air is already at body temperature (37°C) and fully saturated, exerting a vapor pressure of 47 mmHg (points B and B′). In this process, the mucosa, especially that of the nasal cavity, cools by transferring sensible heat to warm the air. The mucosa also cools by transferring latent heat to humidify the air. During expiration, the mucosa recovers some heat and water from the air. The air cools, the mucosa warms up and the temperature of both balances at 32ºC. The air, even with 100% relative humidity, retains less water (point C′) and generates lower vapor pressure (point C). Differences between points C/C′ and A/A′ are correlated with heat and water losses through respiration. Graphic generated in GeoGebra Software (GeoGebra, n.d.).*

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During Inspiration – As a starting point, we will consider the temperature of the nasal mucosa at the end of an expiratory process and the beginning of an inspiratory one at 32°C and equilibrated with the temperature of air present inside the nasal cavity. In this condition, the rates of evaporation and condensation are the same. Inspired air at 20°C and 50% relative humidity holds only 8.62 g of water per cubic meter of air (point A′ in figure 6), which exerts a relative water vapor pressure of 8.74 mmHg (point A in figure 6).

Warming the air - As there is a temperature difference between the inspired air (20ºC) and the nasal mucosa (32ºC), conduction starts to transfer sensible heat from the mucosa to the air, cooling the mucosa and warming the air. During inspiration, a strong turbulent flow is developed through the meatus of the nasal cavity, which results in 1) maximum contact of the inspired air with the surface of the heat exchange mucosa, 2) heat transfer by convection, and 3) maintenance of temperature difference between mucosa and inspired air as high as possible, optimizing heat transfer by conduction. This adequate heat transfer condition extends along the trachea and, as the air travels distally, the temperature gradient between the mucosa and the air gradually decreases until equalization, that is, until the air temperature reaches the body temperature of 37ºC, which occurs at the level of the carina.

Moistening the air – As the air present inside the nasal cavity at the end of an expiratory process is replaced by cooler, drier inspired air, the rate of condensation becomes less than the rate of evaporation. Then the condensation rate increases again to balance, but as the air warms to body temperature, the potential absolute humidity of the air is raised to a high level so that it can hold more water vapor. In other words, the mucosa charges the inspired air with water, saturating it with water vapor. The amount required to reach 100% relative humidity is 43.8 $g*m^{-3}$ (point B′ in figure 6), which exerts a vapor pressure of 46.95 mmHg (point B in figure 6). In the process of evaporation, the mucosa loses heat in the latent form and cools down although the air does not heat up.

During Expiration – We must consider that the air inside the lungs is conditioned at a temperature of 37ºC and fully saturated with water vapor (points B and B′ in figure 6) and that the temperature of the nasal mucosa has cooled down to 30ºC during inspiration (Lindemann et al. 2002). Accordingly, the lowest temperature of the nasal mucosa is at the end of inspiration and the highest one is at the end of expiration.

Cooling the air – The expiration is longer and the flow is even more turbulent than in inspiration favoring heat transfer (Sahin-Yilmaz and Naclerio 2011). As the warm air from the lungs comes into contact with the cooler mucosal surface of the more proximal airways, especially that of the nasal cavity, a temperature gradient transfers sensible heat by conduction from the air to the mucosa. The turbulent flow, replacing the air that cools in contact with the mucosa with warmer air, transfers heat by convection, optimizing the heat transfer by conduction between the air and the mucosa. This process heats the mucosa to 32ºC while the air cools which, in thermal equilibrium with the nasal mucosa, is exhaled at a temperature of 32ºC (point C in figure 6).

Reclaiming water – As air from the lungs cools in contact with the lining of the nasal cavity, the most probable speed of the air molecules decreases, and fewer molecules translate at speeds higher than that of the escape, that is, 719 $m*s^{-1}$. In this condition, more water vapor molecules colliding with the mucosal surface are reintegrated into the liquid phase, i.e., they condensate. In this process, the latent heat of the water vapor molecules is released, heating the liquid phase of the mucosa, but not cooling the air. In other words, as the air temperature decreases and balances with that of the mucosa, its potential absolute humidity drops to a lower level, so it can hold less water vapor and the water that condensate is precisely the water that the mucosa can reclaim. Figure 6 shows that the exhaled air at 32ºC is fully saturated with water vapor (blue lines) and contains 33.74 g of water per cubic meter of air (point C′) generating a vapor pressure of 35.57 mmHg (point C).

Water loss – As the mucosa, during the expiration, cannot recover all the water supplied to condition the inspired air, there is a net water loss per respiratory cycle. The amount of water that evaporate from the mucosa and does not condensate back is the vertical difference between point C′ (33.74 $g*m^{-3}$) and A′ (8.62 $g*m^{-3}$) (figure 6), which is 25.12 $g*m^{-3}$. Considering resting conditions with a tidal volume of 500 mL, the amount of water lost per respiratory cycle is $12,56*10^{-3}$ grams and, at a respiratory rate of 12 per minute, the water loss by breathing is 217 $g*day^{-1}$ (the same as 217 $mL*day^{-1}$). If a person drinks 1.2 liters of water a day, this water loss corresponds to 18% of total water consumption, a significant amount for water balance calculations.

Heat loss – As not all the heat supplied to the inspired air is recovered during expiration, the expired air is warmer than the inspired one and therefore there is a net heat loss per respiratory cycle. The horizontal distance between points C and A (figure 6) is correlated to the sensible heat loss, i.e., the heat that changes the temperature of the air. This kind of heat follows equation 5. However, as the inspired air contains a certain amount of water vapor (50% saturated in the example of figure 6), the specific heat capacity of

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moistened air (c_{ma}) is a combination of the specific heat of dry air (c = 1.005 kJ*kg^{-1}*°C^{-1}) and the specific heat capacity of water vapor (c_{wv} = 1.82 kJ*kg^{-1}*°C^{-1}) according to the following equation:

$$c_{ma} = c + W * c_{wv} \quad (10)$$

where *W* is air specific humidity (kg of water per kg of dry air). In this way, the amount of sensible heat to warm a given mass *m* of moistened air is:

$$Q_S = m * (c + W * c_{wv}) * \Delta T \quad (11)$$

As at 20°C the ratio between the density of dry air and humid air (50% relative humidity) is very close to 1 (Engineering ToolBox 2004), the density of dry air (1.225 kg*m^{-3}) will be considered to find the mass m of air that is heated during inspiration. Then, for a tidal volume of 500 mL, the mass of inspired air is 0.615 grams. Specifically, the amount of heat required to heat 0.615 grams of moistened air (50% relative humidity) from 20° to 32°C (ΔT = 12°C) is lost in one respiratory cycle. Since in point A' (figure 6) the amount of water vapor is 8.62 g*m^{-3}, the mass of water vapor in a tidal volume of 500 mL is 4.31 * 10^{-3} grams. Then, the air specific humidity is:

$$W = \frac{4.3 * 10^{-3} g}{0.6125 g} = 7 * 10^{-3}$$

With these data, we can use equation 11 to calculate the amount of sensible heat that is not recovered and, therefore, lost by the expiration:

$$Q_S = 6.125 * 10^{-4} K = kg \left(\frac{1.005 KJ}{kg * °C} + 7 * 10^{-3} * \frac{1.82 KJ}{kg * °C} \right) * 12°C$$

given Q_S = 7.48 J per respiratory cycle.

In addition, expired air also transports heat in its latent form, that is, the heat needed to humidify the inspired air and not recovered by condensation. This kind of heat, carried into the water molecules in the air, is correlated to the vertical difference between points C' and A' (figure 6), which is the mass of water evaporated during inspiration and not reclaimed by the expiration (12.56*10^{-3} grams as calculated above). Then, the heat required to evaporate this amount of water is the latent heat lost by expiration. Using equation 7 and considering the specific latent heat of water (*L*) of 2.42 kJ*g^{-1} (at 32°C):

$$Q_L = m * L = 12.56 * 10^{-3} g * \frac{2.42 kJ}{g}$$

gives Q_L = 30.39 J per respiratory cycle or 6 watts. In the given example of resting conditions (figure 6), adding sensible and latent heat, the total heat loss by each respiratory cycle reaches 37.87 J or 7.6 watts. Assuming a basal body heat loss of about 80 watts (Wilkes 2001), heat losses through respiration correspond to 9.5%.

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Discussion and Conclusion

Heat and water exchange play an important role in both physiological and pathophysiological processes in the respiratory system. Mucociliary transport, mucus hydration, the concentration of immune molecules, moisture in the alveoli, supply of moisture to dissolve odor particles in the olfactory area, pharyngeal moisture, and recovery of heat and water during expiration are processes directly related to adequate heat and water exchange in the airways (Negus 1952; Kelly et al. 2021; Tosta 2021). Ultimately, the exchange of heat and water in the respiratory tract maintains the structural and functional integrity of the airways and, through loss of heat and water during expiration, participates in water balance and thermal comfort. Disturbances in the process of heat and water transfer between the mucosa of the airways and the air stream, as occurs for example in cystic fibrosis, allergic processes and during mechanical breathing, quickly develop well-known severe symptoms. However, despite the broad physiological spectrum and clinical interests that the subject encompasses, little attention is given to it in physiology textbooks, being treated punctually and superficially. Here, a deeper view is presented, to provide complementary and alternative reference material for students and instructors.

The basic mechanisms underlying the exchange of heat and water in the airways are physical processes that biomedical students commonly leave behind in high school classrooms. Some of these concepts are of fundamental importance and must be rescued and integrated with physiological principles for a clearer understanding of the subject. Following this principle, some basic physics concepts were remembered, which work as building blocks for the construction and development of the theme. In my opinion, this multidisciplinary view is strictly necessary for the conceptualization of the processes of heat and water exchange in the airways.

The main objective of this article is to provide material to facilitate the understanding of the mechanisms underlying the exchange of heat and water in the airways. The theme was developed and delivered through a constructivist sequence, starting from simpler ideas, and progressively moving to more complex ideas, which encompass the previous ones. My perception is that this strategy gradually builds up the concepts and easily engages students in a comprehensive sequence, allowing them to visualize heat and water exchange mechanisms.

It is worth mentioning that here we discussed an example considering an individual in resting conditions at an ambient temperature of 20ºC and relative humidity of 50%. However, the same reasoning can be used to analyze other different conditions, such as a cold or hot environment, physical exercise, feverish states, tracheostomy, and mechanical breathing, among others. I hope this material can be useful for instructors and students interested in this topic.

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EXAM PROGRAM LEADS
Valerie O'Loughlin
Dee Silverthorn
Janet Casagrand

This committee has completed, tested and approved the HAPS Comprehensive Exam for Human A&P and is developing an on-line version of the exam.

EXECUTIVE
Eric Sun

Composed of the HAPS President, President-Elect, Past President, Treasurer and Secretary

FINANCES
Ron Gerrits

NOMINATING
Kerry Hull

This committee recruits nominees for HAPS elected offices.

PRESIDENTS EMERITI ADVISORY COMMITTEE
Mark Nielsen

This committee consists of an experienced advisory group including all Past Presidents of HAPS. The committee advises and adds a sense of HAPS history to the deliberations of the BOD

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