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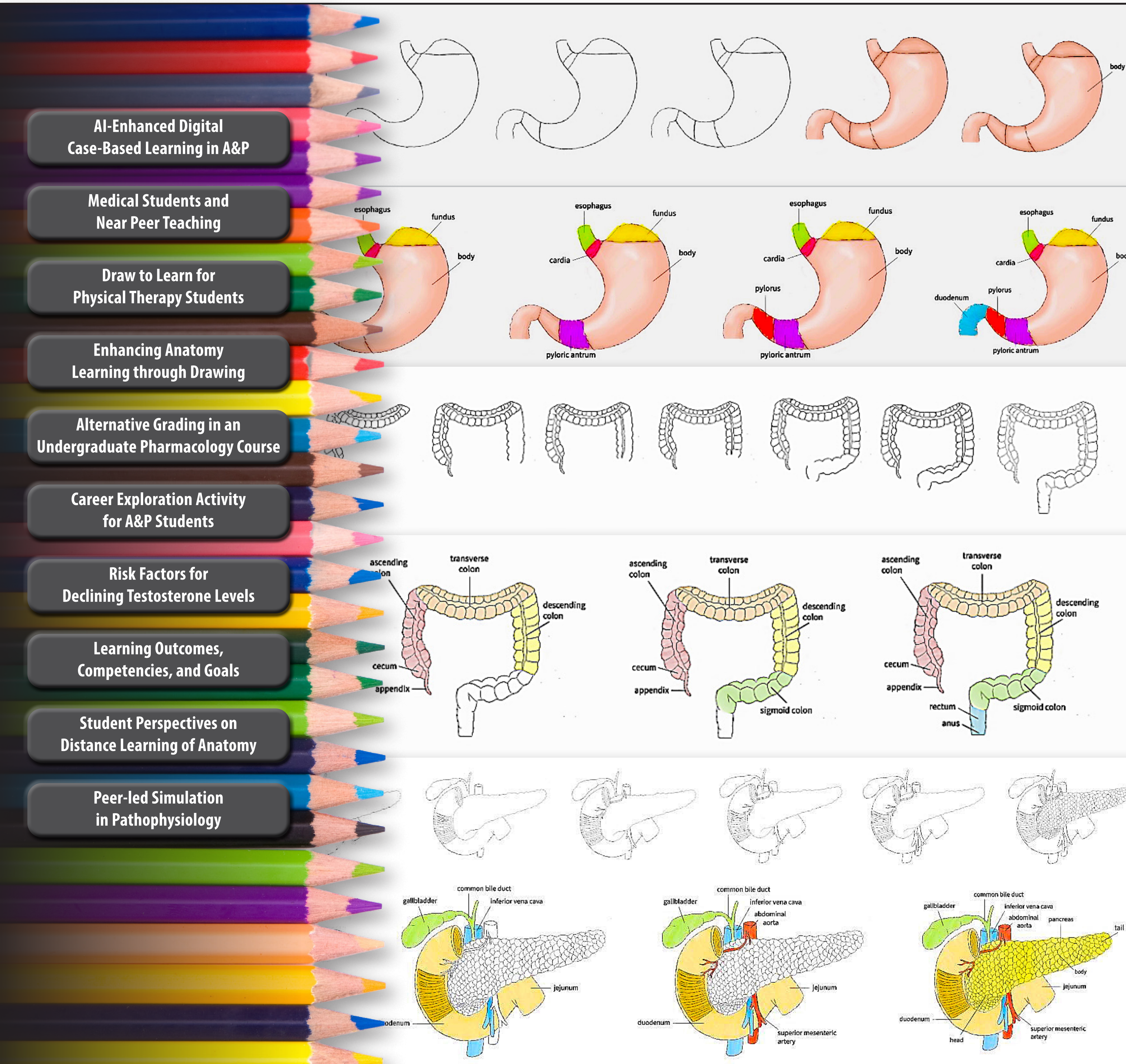

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A Pilot Evaluation of AI-Enhanced Interactive Digital Case-Based Learning in Human Anatomy and Physiology Education

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Abstract

This study evaluated the transition from traditional text-based case studies to artificial intelligence (AI)-enhanced, scenario-based digital cases in a large Human Anatomy and Physiology course. The project included three phases: (1) development of two interactive digital cases on the urinary system, (2) a pilot evaluation with teaching interns (TIs, former students assisting in laboratories), and (3) implementation with enrolled students in BIOL 20400. The digital cases were created using slide-based software and incorporated AI-generated visuals and narration to produce learning experiences that felt more immersive and scenario-driven. During the pilot phase, ten TIs compared traditional and digital formats using the User Experience Questionnaire (UEQ). The digital cases received higher ratings for *Attractiveness*, *Stimulation*, and *Novelty* ($p < 0.05$). In the course-wide implementation ($N \approx 1{,}000$), students completed the User Engagement Scale (UES) to assess four domains of engagement associated with the digital case format. Students reported positive perceptions of *Perceived Usability* and *Aesthetics*, indicating that the activities were visually appealing, easy to navigate, and free from major usability frustrations. *Focused Attention* showed the lowest mean ratings and *Reward* was moderate, patterns that may reflect contextual factors such as group-based completion, time pressure, and varying levels of student interest in the topic. Overall, this study is best interpreted as an engagement-focused pilot that informs instructional design iteration rather than as evidence of improved engagement. The findings highlight how implementation context shapes student engagement with scenario-based learning tools and demonstrate the feasibility of developing visually rich digital cases using widely available tools. https://doi.org/10.21692/haps.2026.001

Key words: immersive learning, scenario-based learning, student engagement, AI-enhanced resources

Introduction

Connecting lecture content to real-world experiences is often the key to making learning "stick," a concept grounded in self-determination theory's principle of relatedness (Deci & Ryan, 2000). This goal is shared by many instructors who teach Human Anatomy and Physiology (A&P), a subject where nearly every concept can be linked to daily life and to common health conditions that affect the people around students. Although this connection might seem straightforward to implement, end-of-semester course evaluations and informal student feedback collected in this course have indicated that not all students respond positively to traditional and group-based approaches used to bridge classroom content with real-world applications, reflecting the well-documented variability in student engagement across instructional contexts (Sinatra et al., 2015).

BIOL 20400 is the second course in the A&P sequence at Purdue University, enrolling more than 1,100 students annually from multiple majors, including those pursuing pre-professional health tracks. The course consists of lectures held in a traditional classroom setting (accounting for 67.6% of the final grade), hands-on labs (23%), and recitations (9.4%). The recitation sessions are designed to help students connect lecture content to real-world applications. These sessions have traditionally relied on text-based case studies that promote analysis and application. However, end-of-semester survey indicated that some students perceived the recitation sessions as having limited value, citing insufficient engagement or a preference for exam-focused review over application-based activities.

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According to Sinatra et al. (2015), meaningful learning depends on behavioral, cognitive, and emotional engagement. Scenario-based learning is a powerful way to encourage engagement by placing students in authentic narratives that require them to think critically, analyze information, and make decisions. When combined with multimedia learning principles (Mayer, 2009; Clark & Mayer, 2016), such scenarios can reduce cognitive overload and support learner motivation through the use of visuals, narration, and story elements that make learning experiences more authentic.

In this study, cognitive overload is defined as excessive mental effort imposed by poorly structured or overly complex instructional materials, which can interfere with learning in content-dense courses such as A&P. Accordingly, the digital cases were designed using established multimedia principles to minimize unnecessary cognitive demands related to information presentation, rather than to directly measure cognitive load as an outcome.

Historically, the high cost of technology and the specialized expertise required to develop interactive materials placed the creation of rich, multimedia learning experiences primarily in the domain of professional instructional designers. Today, the increasing availability of affordable digital and artificial intelligence (AI) tools enables educators to take a more active role in designing immersive, context-specific learning experiences tailored to their students' needs. As these tools become more accessible and practical, they offer new avenues to create learning experiences that feel more authentic and personally meaningful in A&P education.

Recent evidence suggests that AI-assisted problem- and case-based learning may support student knowledge acquisition and learner satisfaction, although outcomes vary depending on implementation context (Wei et al., 2025). This study piloted a transition from traditional text-based cases to AI-enhanced, scenario-based e-learning through two instructor-developed digital cases focused on the urinary system. Each case presented a distinct narrative style—one emphasizing realistic clinical context and the other incorporating a more gamified, video-game-like format. The goal was to explore whether a digital, scenario-based format could support student engagement in A&P without increasing cognitive load.

Methods

The project was organized into three stages: (a) designing and developing two digital, scenario-based case studies; (b) piloting the cases with teaching support staff who provided usability feedback; and (c) implementing the cases at scale with enrolled students to evaluate engagement and usability.

(a) Development of the Scenario-Based Case Studies
Two digital cases with distinct narrative styles were developed by the course instructor (Dr. Castro) to accommodate diverse student preferences and engagement styles. The instructional goal of both cases was to support student engagement through narrative context and interactive design, rather than to directly assess learning outcomes.

The first case, *The Enigmatic Case of Mrs. Anderson's Acute Renal Distress*, was designed as a realistic, contemporary medical scenario addressing the anatomy and physiology of the urinary system (Figure 1). It explored how dietary factors—particularly calcium and oxalate absorption—and malabsorptive bariatric surgery can contribute to kidney stone formation.

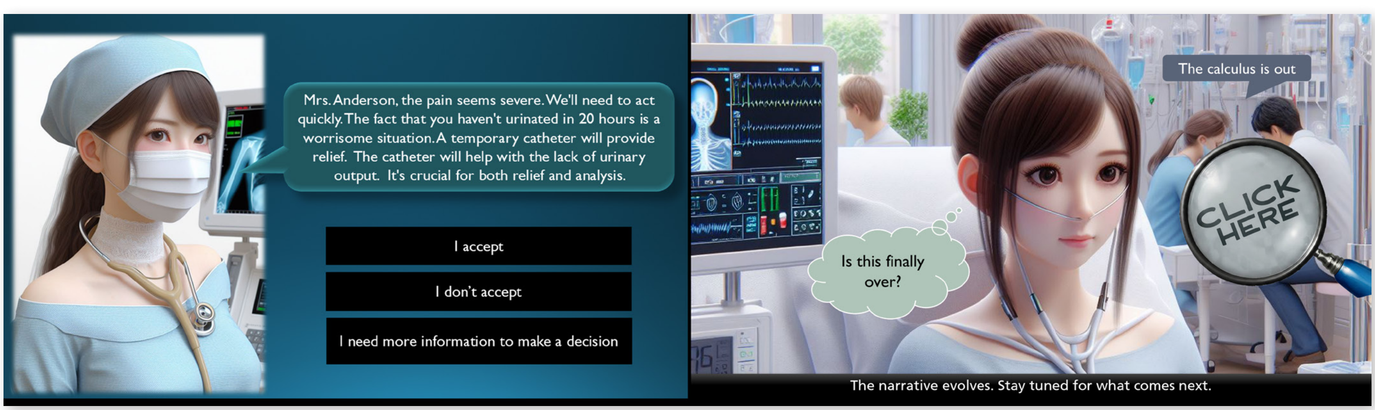

Figure 1. *Sample scenes from* The Enigmatic Case of Mrs. Anderson's Acute Renal Distress *showing AI-generated visuals created with ChatGPT-4. Interactive elements, including hyperlinks and slide-to-slide navigation, were incorporated using slide-based software to simulate case exploration.*

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The second case, *The Healer's Dream*, adopted a more imaginative, gamified style, guiding students through a medieval setting in which they investigated the mysterious cause of a king's death—gout, influenced by a nephron transport defect. Historical and cultural elements were integrated throughout the story, including the role of minstrels in narrating events and references to early medical beliefs about the "disease of kings" (Figure 2).

Both modules were created in slide format (20–25 slides each) using Microsoft PowerPoint to integrate interactive elements and scenes. Each scenario incorporated hyperlinks, animations, and transitions to simulate exploration and discovery, along with visual cues such as clickable objects that revealed brief text or audio explanations when selected. Licensed educational videos from Alila Medical Media were embedded to support concept understanding and strengthen connections with lecture content. Narrative visual assets, including environmental backgrounds and character illustrations, were generated using ChatGPT-4; voiceovers were produced with ElevenLabs™. This approach aligns with recent perspectives emphasizing the use of generative AI as a creative and supportive tool in case-based learning, in which AI enhances narrative design and learner experience while pedagogical control and content accuracy remain under instructor oversight (Stretton et al., 2024).

The finished scenarios were exported in SCORM format to ensure compatibility with Brightspace, the learning management system (LMS) used at Purdue University. The modules were embedded directly within the course site and only enrolled students could access them.

(b) Teaching Support Staff Pilot Phase

Before launching the new digital cases to students, a pilot evaluation was conducted during the Fall 2024 semester involving undergraduate Teaching Interns (TIs) supporting BIOL 20300, the first course in the A&P sequence. The purpose of this phase was to gather feedback from individuals familiar with course content and student learning dynamics.

An invitation email describing the study and its voluntary nature was distributed to all 70 members of the instructional team: 16 graduate TAs and 54 undergraduate TIs. Participation was voluntary, and only undergraduate TIs elected to attend the pilot session; no graduate TAs participated. TIs are former students of the course who were assisting in laboratory instruction. This project was approved by the Institutional Review Board of Purdue University (IRB #2024-332), and informed consent was obtained from all participants.

Participants attended a one-time, in-person session held in a computer classroom. During the session, they interacted with three case-study formats:

- Format 1: A traditional text-based case used in the same course the previous year, based on slide format with minimal interactivity (some clickable elements)
- Format 2A: *The Enigmatic Case of Mrs. Anderson's Acute Renal Distress*
- Format 2B: *The Healer's Dream*

Each case was explored for 15 minutes, followed by completion of the User Experience Questionnaire (UEQ) (Laugwitz et al., 2008), a validated instrument that measures user perceptions of interactive products across six dimensions: *Attractiveness*, *Perspicuity*, *Efficiency*, *Dependability*, *Stimulation*, and *Novelty*. All surveys were completed anonymously and deposited into a sealed collection box at the end of the session to maintain confidentiality.

Survey responses were entered and analyzed using the UEQ Data Analysis Tool (https://www.ueq-online.org).

Figure 2. *Sample scenes from* The Healer's Dream, *illustrating interactive features and a gamified narrative style intended to encourage interaction and sustained attention.*

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(c) Student Implementation Phase

The large-scale student implementation took place during the Spring 2025 semester in BIOL 20400. The two digital cases were integrated into the existing recitation curriculum once the lecture component reached the urinary system unit, spanning two of eleven recitation sessions. The remaining sessions continued to use traditional text-based cases similar to Format 1.

Students were instructed to complete each scenario individually at home prior to their scheduled recitation session. During recitation, they worked collaboratively in small groups to apply lecture concepts to case-specific prompts. Questions were designed to be highly specific, requiring detailed engagement with the case materials. This design emphasized engagement with the scenario context rather than performance-based differentiation among students. Examples of scenario-based discussion questions used during the implementation phase are shown in Table 1.

During the same semester, students completed an online survey via Qualtrics as part of a scheduled class activity. Student engagement with the AI-enhanced digital cases was assessed using the User Engagement Scale–Long Form (UES-LF) (O'Brien et al., 2018). The instrument included 30 items distributed across four engagement dimensions: *Focused Attention* (7 items), *Perceived Usability* (8 items), *Aesthetics* (5 items), and *Reward* (10 items). Each statement was rated on a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). Eight items (PU-1 through PU-6, PU-8, and RW-3) were reverse-coded following the published scoring instructions.

Two complementary analyses were conducted:

- First, to align with O'Brien et al., 2018's methodology, scores were averaged for each subscale and for the overall engagement index, providing a summary of general engagement patterns across dimensions.
- Second, to explore the response variability within each dimension, item-level percentages were examined using merged response categories (Agree, Neutral, Disagree).

This project was supported by a grant from the Purdue Innovation Hub (Purdue's Innovation College).

CASE 1
In which body region does Mrs. Anderson, the patient, experience pain?
Why did this patient undergo RYGB (Roux-en-Y Gastric Bypass) surgery?
What three abnormalities were detected in the patient's urinalysis?
In which organ of the urinary system is the calculus located in this patient?
What was the composition of the calculus, and how does that relate to urinalysis results?
CASE 2
How does the mention of autumn crocus provide insight into medieval medicine and its approach to treating this "mysterious illness"?
The minstrel refers to "imbalances within the blood." How does this reflect the humoral theory that dominated medieval medical beliefs?
The king's condition is described as similar to his father's ("gutta artetica"). What does this imply about the nature of his illness?
Why was it historically called "the disease of kings"?
What are the names of the "strange lumps" around the king's ears and on his finger? What pathophysiological process leads to the formation of these lumps? Why do they develop in fingers and ears?
Which gene mutation contributed to the king's illness, and what is the function of the protein it encodes in the nephron?

Table 1. *Representative Scenario-Based Questions Used*

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Results

Teaching Intern Pilot (User Experience Questionnaire)

Ten TIs participated in the pilot evaluation during Fall 2024; no graduate TAs participated. Based on UEQ results, the interactive case formats received significantly higher mean ratings than the traditional text-based format for *Attractiveness*, *Stimulation*, and *Novelty* ($p < 0.05$). No significant differences were observed for *Perspicuity*, *Efficiency*, or *Dependability* (Figure 3). These findings suggest that the AI-enhanced interactive cases were perceived as more visually appealing and novel by participants familiar with the course.

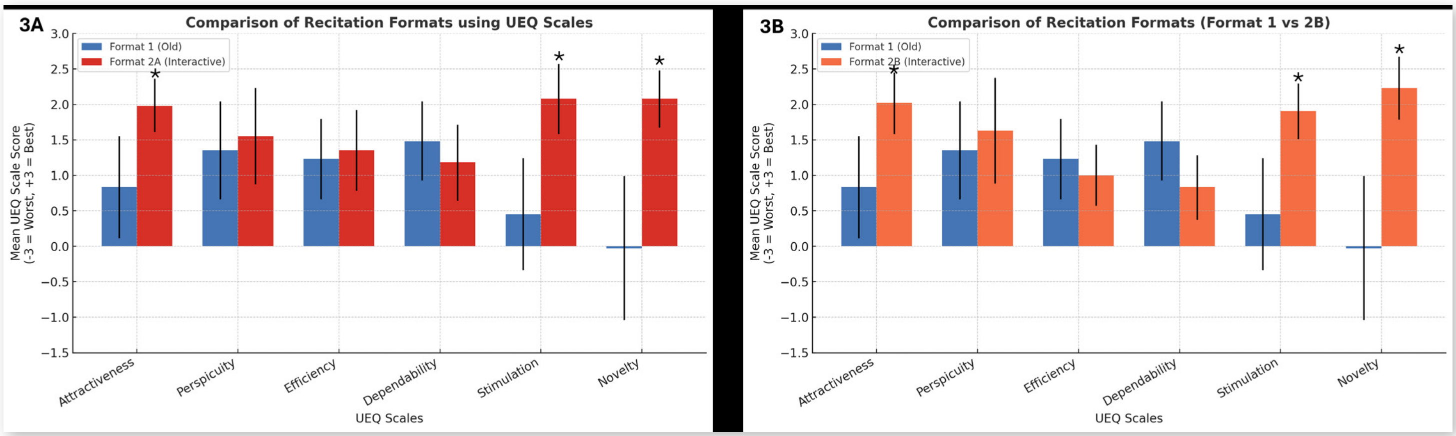

Figure 3. *Mean User Experience Questionnaire (UEQ) scores from Teaching Interns (N = 10) comparing traditional and interactive case formats. Interactive cases were rated significantly higher for Attractiveness, Stimulation, and Novelty ($p < 0.05$).*

(b) BIOL 20400 Students (User Engagement Scale – Long Form)

Following the scoring procedures described in the Methods section, the UES-LF data were analyzed in Microsoft Excel to examine student perceptions of engagement with the AI-enhanced digital cases. Student survey responses showing no variation across all UES-LF items (n = 32) were excluded from analysis to minimize potential bias from rapid or non-reflective survey completion, consistent with prior survey-based engagement research. A total of *N* = 949 students' responses were included in the final analysis.

Figure 4 shows the mean and standard deviation for each dimension. Among the four dimensions, *Aesthetics* (M = 3.41, SD = 0.84) and *Perceived Usability* (M = 3.35, SD = 0.78) had the highest mean ratings, indicating generally positive perceptions of visual design and usability. *Reward* showed moderate levels (M = 2.99, SD = 0.80), while *Focused Attention* was lowest (M = 2.34, SD = 0.80), indicating limited absorption or flow during the activity. The *overall engagement score* averaged 3.04 (SD = 0.63), reflecting an overall neutral level of engagement across participants.

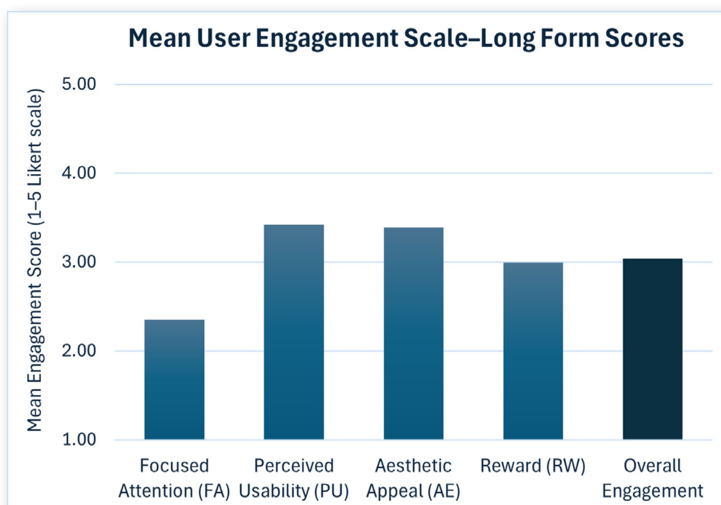

Figure 4. *Mean User Engagement Scale–Long Form (UES-LF) scores by dimension for BIOL 20400 students (N = 949). Scores range from 1 (Strongly Disagree) to 5 (Strongly Agree). Bars represent mean values only.*

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Item-level response distributions were also examined to capture variability within each engagement dimension.

Focused Attention (FA)
Across all seven items, disagreement ranged from 46.6% to 68.9%, with the strongest disagreement for *"I was so involved in this experience that I lost track of time"* (67.5%) and *"When I was using the e-learning scenarios, I lost track of the world around me"* (68.9%). The highest agreement (25.5%) occurred for *"I was absorbed in this experience."*

Perceived Usability (PU)
For negatively worded items such as *"I felt frustrated while using these e-learning scenarios"* and *"I felt discouraged while using these e-learning scenarios,"* disagreement was high (49–67%), indicating that most students did not find the activity confusing or frustrating. The positively framed item *"I felt in control while using these e-learning scenarios"* had the highest agreement (48.8%).

Aesthetics (AE)
Figure 5 shows the percentage distribution of responses for the AE dimension. Agreement ranged from 29.0% to 65.4%, with the strongest endorsement for *"I liked the graphics and images of the e-learning scenarios"* (65.4%) and *"The e-learning scenarios appealed to my visual senses"* (64.6%). Neutral responses ranged from 19–40%, while *Disagree* responses remained low (14.6–30.6%). Overall, students viewed the digital cases as visually appealing and well organized.

Reward (RW)

Figure 6 presents the distribution of responses for the RW dimension. Agreement levels varied across items, with the highest endorsement for *"I consider my experience a success"* (53.4%), followed by *"Using the e-learning scenarios was worthwhile," "I felt involved in this experience,"* and *"This experience was fun,"* each selected by approximately 42% of respondents. In contrast, the highest level of disagreement was observed for *"I continued to use the e-learning scenarios out of curiosity"* (63.9%).

Discussion

The present study examined student engagement with AI-enhanced, scenario-based digital cases in a large-enrollment Human A&P course. The urinary system was deliberately chosen for this pilot because, based on the instructor's experience and supported by previous research (Roberts et al., 2016), it is often perceived as less engaging than other body systems, such as cardiovascular or muscular systems.

Feedback from TIs, who were familiar with the traditional text-based cases from previous years, confirmed that the digital versions were perceived as clear, functional, and visually appealing—findings consistent with higher UEQ scores for *Attractiveness*, *Stimulation*, and *Novelty* ($p < 0.05$). Similarly, large-scale student responses on the UES-LF indicated the

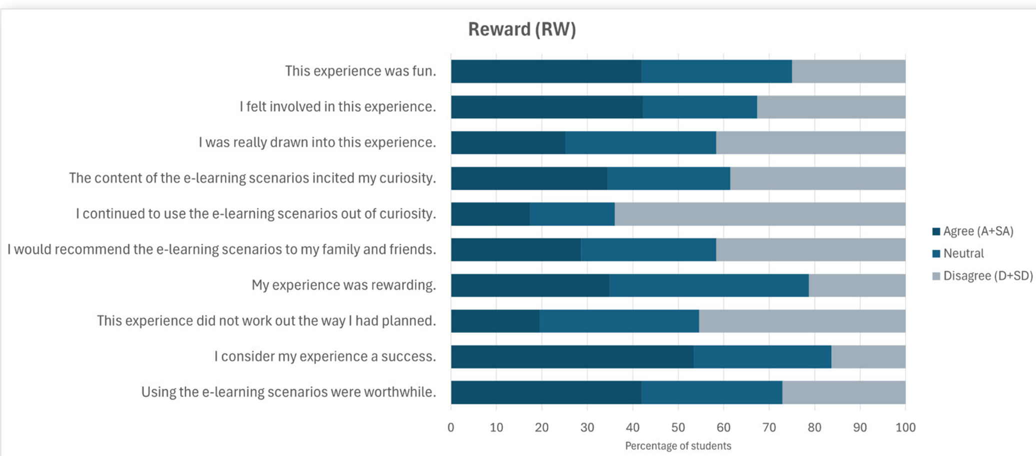

Figure 5. *Percentage distribution of student responses for the Aesthetics dimension of the User Engagement Scale–Long Form (UES-LF). Categories are merged as Agree (4–5), Neutral (3), and Disagree (1–2).*

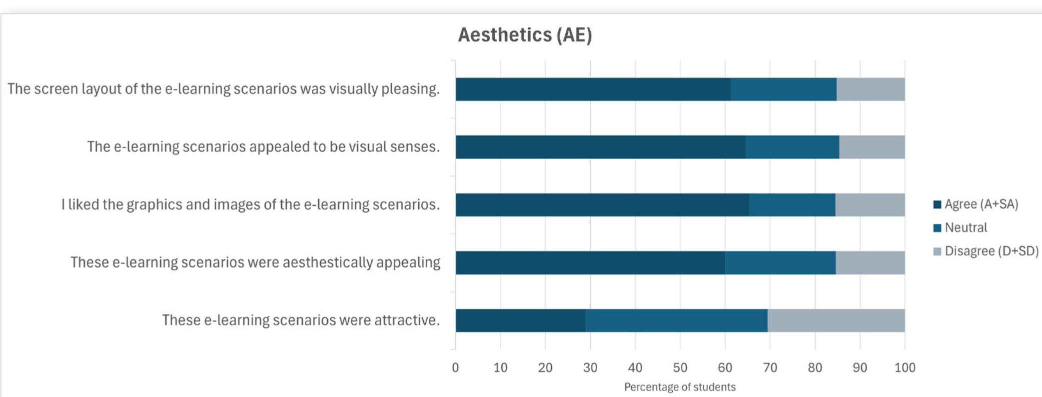

Figure 6. *Percentage distribution of student responses for the Reward dimension of the User Engagement Scale–Long Form (UES-LF). Categories are merged as Agree (4–5), Neutral (3), and Disagree (1–2).*

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strongest agreement in the AE and PU dimensions, suggesting positive perceptions of visual design and usability among more than half of the students. It is also noteworthy that, when examining individual items within the RW dimension, approximately 42% of students reported feeling that the experience was worthwhile, rewarding, or enjoyable. In a sample of 949 students, this represents nearly 400 learners who found the activity personally meaningful—even for a less appealing topic—highlighting the value of small gains across large cohorts. These findings are consistent with broader evidence comparing digital and paper-based case formats. A systematic review by Zarea Gavgani et al. (2015) found that while digital case scenarios produced learning outcomes comparable to traditional paper-based versions, they generated substantially higher levels of student satisfaction and were considerably more time-efficient for both learners and instructors. Similarly, in this study, students rated the AI-enhanced cases as visually appealing and easy to navigate, suggesting that PU and AE quality may play a central role in sustaining engagement even when cognitive demands remain constant. At the same time, the overall engagement score remained neutral (M = 3.04), and several User Engagement Scale items related to focused attention and affective response (e.g., feeling drawn to the experience or finding it rewarding) received low agreement ratings, indicating that the intervention did not uniformly engage students across all dimensions of engagement.

In BIOL 20400, recitation sessions have traditionally relied on instructor-created case studies designed to help students connect lecture concepts to real-world applications. The original long-text versions used during the instructor's first year of teaching were gradually refined into shorter, slide-based cases presented as brief stories with simple icons and limited interactivity. These "traditional" cases already incorporated brief narratives and clickable navigation elements, making them more interactive than static reading assignments. Although some students informally described these as more engaging than typical text-based exercises, they still failed to sustain interest among many learners. The AI-enhanced, scenario-based approach represented the next step in this instructional progression—building upon that interactive foundation by integrating richer narratives, sound, and AI-generated visual environments to foster deeper immersion and contextual understanding. Given that the earlier format already included some interactivity, stronger differences in overall engagement might be expected when comparing the AI-enhanced cases to fully traditional, text-only activities.

The class activities associated with the cases were intentionally designed to be case-specific and context-dependent. While some items addressed core physiology or anatomy concepts that could theoretically be found online or through AI tools, the structure of the prompts required students to connect that foundational knowledge back to the specific clinical or historical scenario. This design likely demanded a degree of cognitive engagement that depended on students' prior preparation. One factor that may have contributed to the lower FA and RW scores relates to the implementation context. Although students were instructed to complete the scenarios individually before their recitation sessions, completion could not be verified, and it is likely that many encountered the cases for the first time during the in-class activity. Given the 50-minute time constraint and the collaborative nature of the sessions, some students may have felt pressure to move quickly through the scenarios to focus on answering the graded activity questions. This interpretation aligns with informal feedback shared during office hours in previous semesters, where students noted that unequal preparation among team members can limit discussion depth and overall engagement—an issue also described in the team-based learning literature (Michaelsen & Sweet, 2008). Consequently, engagement levels in this pilot may have been influenced by contextual factors such as group dynamics and time pressure, rather than reflecting the effects of the learning tool design alone.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, the evaluation focused on student engagement and user experience rather than learning outcomes or exam performance. In BIOL 20400, recitation activities are intentionally designed as low-stakes assignments that contribute a small proportion of the final course grade and are typically completed collaboratively in groups of four to five students. As a result, most students receive full credit for these activities, producing limited score variability and restricting the ability to conduct meaningful comparisons of academic performance across instructional formats. Under these conditions, neither recitation grades nor related lecture exam questions provided a valid measure of individual learning gains or perceived success attributable to the AI-enhanced cases.

Second, the collaborative structure of the recitation sessions introduced variability in how individual students engaged with the case materials. Informal observations and student feedback suggested that groups often divided questions among members, which may have limited individual exposure to the full narrative and interactive elements of each scenario. This group-based approach also complicates interpretation of performance on lecture exam questions related to recitation content, as students may not have personally engaged with all aspects of the case material. Similar challenges have been reported in technology-enhanced and online case-based learning environments, where collaborative group structures can mask individual engagement and complicate interpretation of learning outcomes (Donkin et al., 2023).

Third, although students were instructed to complete the digital cases individually prior to their recitation sessions, completion could not be verified. It is therefore likely that some students encountered the cases for the first time during the in-class activity. Given the 50-minute time constraint of recitation sessions and the requirement to complete graded prompts, students may have prioritized answering questions over fully

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exploring the scenarios. Although time-on-task was not a predefined outcome of this study, descriptive LMS access data indicated that students spent, on average, under 10 minutes interacting with each digital case. Given that each scenario consisted of 20–25 interactive slides, this observation suggests that some students may not have engaged with all elements of the cases prior to or during recitation. Because these data were examined post hoc and were not linked to individual engagement responses, they are reported here solely to provide contextual insight into the observed engagement patterns. This implementation context may have contributed to the low FA scores observed in the User Engagement Scale and suggests that engagement levels were shaped not only by the design of the learning tool but also by time pressure and group dynamics.

Fourth, while multimedia design principles were intentionally applied to avoid cognitive overload, cognitive load was not measured directly in this study. Instead, inferences were drawn indirectly from usability-related dimensions of the engagement instruments, such as perspicuity and perceived usability. Although students did not report high levels of frustration or confusion, these measures do not provide a comprehensive assessment of intrinsic cognitive load or unnecessary demands related to information presentation.

Finally, this study represents a single-course, single-institution pilot focused on one content area (renal physiology) within a broader A&P curriculum. The findings may therefore not generalize to other physiological systems, course structures, or instructional contexts.

Together, these limitations underscore that the present work should be interpreted as an exploratory evaluation of engagement and usability, rather than a definitive test of learning effectiveness.

Design Implications

For these reasons, this pilot evaluation focused on student engagement and usability rather than learning outcomes. Rather than interpreting neutral engagement scores as evidence of ineffective design, the findings highlight how implementation context can constrain engagement with scenario-based learning tools. Together, the findings and limitations of this pilot evaluation informed a redesign of recitation activities in BIOL 20300 and BIOL 20400 that was implemented in the following academic year (2025-2026). The redesigned recitation sessions now adopt an in-person, fully individual format integrating interactive, AI-enhanced scenario-based learning across all body systems. To address constraints identified in the pilot, recitation sessions were redesigned to emphasize individual accountability and full interaction with case content.

Students now engage directly with digital scenarios on their laptops, which are accessible only during the 50-minute recitation period. Access to the associated graded quiz is gated such that students must complete all components of the digital case before the assessment is unlocked. After completing each scenario, students "unlock" an interactive digital activity tailored to the case, which remains available for several days. This approach is intended to ensure that each student interacts with the full narrative, visual elements, and embedded explanations prior to responding to application-based questions, while allowing students to engage with scenario scenes at their own pace and complete follow-up activities outside of class if needed. By shifting to individual completion and gated access, the redesigned format is intended to promote greater individual accountability and more consistent exposure to case content.

From a design perspective, the development of these digital scenarios demonstrates how current technologies enable instructors to create professional-quality learning tools without advanced programming skills or high costs. Each scenario was created in PowerPoint and integrated AI-generated visuals, voices, and environmental scenes to provide realism and context. AI was used exclusively for creative enhancement, not for information delivery or student interaction, and scientific accuracy was ensured by linking to reliable educational resources through embedded hyperlinks. This approach illustrates how AI can support narrative design and learner experience while pedagogical control remains firmly with the instructor, and how the combination of instructor expertise, narrative design, and AI-assisted creativity can help instructors create learning experiences that are personal, immersive, and pedagogically sound.

Importantly, this work is best interpreted not as a demonstration that AI-enhanced cases increase student engagement, but as an AI-informed instructional design iteration that uses engagement data to identify implementation constraints and guide subsequent course redesign. Taken together, these design implications emphasize that the value of AI-enhanced scenario-based learning lies not solely in the technology itself, but in how such tools are embedded within instructional structures that promote individual accountability, sufficient time-on-task, and meaningful interaction with content. The present study contributes practical insights into how engagement-focused pilot evaluations can inform evidence-based instructional redesign in large-enrollment, content-intensive courses.

About the Authors

Beatriz Castro, PhD, is a lecturer at Purdue University whose teaching focuses on human anatomy and physiology. She leads the LearnerX Lab, which explores ways to support student engagement through experiential learning and the design of innovative instructional tools. At the time of the study, Gabriela Conjelko and Samantha Johnson, members of the LearnerX Lab, were majoring in biology (pre-med track) and nutrition and dietetics, respectively. They contributed to data interpretation and the writing and editing of the manuscript.

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EDUCATIONAL RESEARCH

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Asynchronously Instructing Medical Students to Near-Peer Teach

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Abstract

This study explored the lived experiences of medical students who were trained as near-peer teachers through an asynchronously designed program to teach the ultrasound component of the human anatomy lab. The study examined the challenges perceived by the near-peer teachers, dealing with those challenges, and the impact of an asynchronous instructional program on the near-peer teachers. Using a qualitative phenomenological design, semi-structured interviews were conducted with second-year medical students (N = 10) who participated in the program. Deductive thematic analysis revealed four key themes: (1) concerns regarding increased workload and time commitment, (2) approaches to overcoming challenges during NPT training, (3) perceived benefits of asynchronous instruction, and (4) suggestions for improving NPT training. Findings highlight the effectiveness of asynchronous instruction in supporting the training and performance of NPTs by offering flexibility, self-paced learning, and reduced scheduling conflicts. The results suggest broader applicability of this instructional approach in other areas of medical education, including clinical and gross anatomy labs. Participants also recommended incorporating a hybrid model to enhance the design and delivery of near-peer teaching programs.
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Key words: near-peer teaching, near-peer teacher training, asynchronous instruction, ultrasound training

Introduction

Ultrasound is becoming increasingly popular in medicine due to its versatility in diagnosing pathologies and its use in various procedures (Ben-Sasson et al., 2019; So et al., 2016). As technology has developed, ultrasound units have become more portable and are known for their safe and non-invasive nature compared to other imaging modalities that use ionizing radiation (Smith et al., 2018; Smith et al., 2017; So et al., 2016; Swamy & Searle, 2012). In their future specialty, many medical students will incorporate some form of ultrasound usage (Amini et al., 2015; Dreher et al., 2014).

A shortage of qualified faculty to teach ultrasound imaging at the level needed by future physicians has become a significant problem in medical schools, leaving a gap in the instruction (Cowan et al., 2021; Smith et al., 2020, 2021; Smith et al., 2017). One strategy that may be used in medical education to ease the challenge of the lack of qualified faculty to train ultrasound imaging is near-peer teachers (NPT). (Smith et al., 2018, 2020, 2021; Smith et al., 2017).

Near-peer teaching refers to a more experienced or senior student offering assistance and guidance to a fellow student (Khapre et al., 2021). Research has demonstrated the effectiveness of near-peer teaching in medical education, which may be a possible solution to the shortage of qualified faculty for teaching ultrasound. Near-peer teaching has been shown to be beneficial to both active groups within the educational process and the teaching of specific skills required for future practice (Ben-Sasson et al., 2019; Smith et al., 2018, 2021). Additionally, for NPTs, the process of teaching should serve to reinforce the knowledge and skills attained in earlier studies.

Near-peer teaching has become increasingly prominent in medical school curricula. Much of the existing research has focused on outcomes for the learners, the near-peer teachers' perceptions of their teaching experiences, or the broader curricular impact of NPT interventions (Guerrero-Mendivil et al., 2023). However, one aspect that remains underexplored is

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the formal instruction and preparation of near-peer teachers themselves (Guerrero-Mendivil et al., 2023).

Formal training for students involved in near-peer teaching is rarely provided by medical schools (Wisco et al., 2023). Instead, these students often assume teaching roles based on their motivation to deepen their understanding after completing the previous year's coursework (Guerrero-Mendivil et al., 2023). To ensure high-quality instruction, it is essential that these educators receive structured training in both subject matter expertise and pedagogical techniques (Guerrero-Mendivil et al., 2023; Wisco et al., 2023; Zheng & Wang, 2022).

A comprehensive review of the literature reveals a clear need for further research aimed at identifying the most effective components of instructional programs for NPTs. Currently, the instruction of NPTs in medical schools is often informal and improvised, raising concerns about the adequacy of their teaching preparation (Guerrero-Mendivil et al., 2023). Preliminary findings suggest that implementing formal, structured training focused on needs-based educational skills may better equip NPTs to navigate instructional challenges than those who receive minimal or no formal training (Alvarez et al., 2017; Guerrero-Mendivil et al., 2023).

While many studies have evaluated the effectiveness of near-peer teaching itself, few have examined the training methods used to prepare NPTs. To address this gap, it is important to investigate instructional approaches that can prepare NPTs both efficiently and effectively. Asynchronous online learning presents a promising modality in this context, offering the advantages of systematic design and the flexibility to accommodate the demanding schedules of medical students.

One significant concern for medical students serving as NPTs is the time commitment required, which can detract from their second-year coursework and academic responsibilities (Kruskie et al., 2023). Bickerdike et al. (2016) stated that the association between academic success and time management skills has been studied, revealing a positive correlation between good time management and academic achievement. According to Alzahrani et al. (2022), effective time management is essential as it can directly affect the learning process. One solution to balancing the time demands in medical school and near-peer teaching aspirations is to use asynchronous learning to instruct the NPT. Medical students tend to view asynchronous learning favorably, largely due to its flexibility in accessing instructional materials and accommodating diverse learning preferences (Alzahrani et al., 2022; Habibpour et al., 2022). Habibpour et al. (2022) stated, that the positive experiences medical students expressed in their research study on asynchronous learning included the removal of limitations on the time and place where the learning occurs, the ability to watch the content multiple times, and the opportunity for learning independently.

This qualitative study aimed to explore the challenges associated with instructing NPTs and the strategies they employ to overcome them. Specifically, it examined the lived experiences of medical students who were trained asynchronously to teach ultrasound imaging using online modules systematically designed according to Merrill's First Principles of Instruction (FPI). The study was guided by three central research questions: (1) What are the experiences of medical students undergoing asynchronous training as NPTs? (2) What challenges do they encounter, and how do they address them? (3) What are their perceptions of effective instructional approaches? By investigating these areas, the study seeks to enhance understanding of the impact of asynchronous training and contributes to the development of more effective instructional programs for NPTs.

Methods

Research Design

To address the research questions, this study employed a qualitative phenomenological research design to gain an in-depth understanding of the effectiveness of asynchronous instruction for medical students serving as NPTs. The phenomenological research design investigated the collective importance of individual participants' experiences of the phenomenon (Creswell & Poth, 2016). Data collection involved semi-structured interviews with each of the NPTs following the completion of two ultrasound labs. The interviews focused on the NPTs' lived experiences and their preparation for teaching near peers.

Study Participants

The study participants were second-year medical school students at a southwestern osteopathic medical school. During the previous year, this study's lead researcher was an instructor for the participants in the ultrasound and gross anatomy labs. By providing instruction in the ultrasound lab, the researcher understands how the lab environment works and the challenges the participants face.

In qualitative research, it is essential for researchers to recognize their own biases (Creswell & Poth, 2016). In this study, the researcher was involved in participant recruitment, intervention design, and data analysis. To minimize potential bias arising from the researcher's teaching relationship with the near-peer teachers, interviews were conducted by other members of the research team experienced in qualitative interviewing.

Participant Recruitment

The researcher used convenience and criterion sampling to select participants who could contribute valuable insight to answer the research questions. Convenience sampling involves selecting participants for a sample based on their availability and willingness to participate (Merriam & Tisdell, 2016). According to Creswell & Poth (2016),

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criterion sampling involves selecting participants with previous experience in the task and meeting the criteria set forth. The criterion for sampling included applicants who applied to the NPT program, achieved good academic standing by the end of their first year of medical school, and successfully completed the ultrasound component in the human anatomy lab course during the previous academic year. Ten near-peer teachers (four males, six females) were purposefully selected from a cohort of 194 second-year medical students (OMS-2), all of whom completed the study.

Participants in the study were provided with an IRB-approved consent form during an in-person meeting on campus. They were given the opportunity to ask questions and provide consent. All NPTs who instruct in the human anatomy lab's gross anatomy or ultrasound components are compensated by the institution. The research study participants did not receive any extra compensation for their online, asynchronous instruction.

Design of the Near-Peer Teacher Instruction

David Merrill's FPI provided the foundational framework for designing the intervention. Merrill (2020) formulated FPI by synthesizing a variety of existing instructional design theories and models. The framework outlines five core principles for effective learning: (1) engaging learners in solving real-world problems, (2) activating prior knowledge to support new learning, (3) demonstrating new knowledge, (4) encouraging learners to apply what they have learned, and (5) integrating new knowledge into real-life contexts. These principles informed the design and development of two online asynchronous instructional modules for near-peer teachers in the ultrasound lab.

Instruction and Teaching Lab Processes

Following the asynchronous instruction, the NPTs provided teaching support to first year medical students (OMS-1) in two labs using ultrasound imaging to reinforce normal anatomy. All OMS-1 students (n = 194) participate in two 1-hour live ultrasound scanning sessions focusing on regional anatomy taught in conjunction with other components of the human anatomy lab course. The OMS-1 students were divided into four groups of approximately 50 students: Group 1 (n = 47), Group 2 (n = 52), Group 3 (n = 49), and Group 4 (n = 46). Each group is assigned a specific one-hour time slot for their ultrasound lab. During the lab session, the OMS-1 students work in teams of two to three per treatment table, with a standardized patient acting as a model. At each treatment table during the ultrasound lab, a dedicated hand-held ultrasound device is provided for the scanning. During each one-hour ultrasound lab session, 2–3 NPTs were assigned to assist a group of approximately 50 OMS-1 students. The NPTs rotated among the small groups of OMS-1 students to provide guidance, answer questions, and offer hands-on support. This structure allowed for targeted instruction while maintaining a manageable student-to-NPT ratio throughout the session.

Data Collection

After the NPTs finished the second ultrasound lab, the researcher scheduled an individual interview with each of the ten participants. The semi-structured interview conducted by research team members used a set of questions to guide the conversation but allowed the flexibility to explore other topics that emerged (see Appendix 1). To ensure that the interview questions addressed the research questions, a group of experts reviewed them prior to administration. The semi-structured interviews were conducted in a private conference room and were audio-recorded for transcription. Interviews lasted between 24 to 42 minutes, with the average interview lasting 30 minutes.

Data Analysis

The research team organized, transcribed, and coded the audio recordings using NVivo14 software (Lumivero, 2020). The research team transcribed verbatim and coded the audio-recorded interviews using a deductive analysis approach. A deductive approach involves creating an organizing framework for codes prior to reviewing the transcript. These priori codes included (1) challenges of near-peer teacher instruction, (2) handling the challenges of being trained as a near-peer teacher, and (3) perception of best practices for instruction near-peer teachers. The process of coding involved identifying patterns and recurring phrases within collected data (Adu, 2019; Creswell & Poth, 2016). The research team thoroughly reviewed all transcripts and explored larger ideas emerging from the interviews. To enhance reliability and minimize bias, two research team members independently coded the transcripts. To ensure interrater reliability and coding consistency, a consensus approach was employed: coders met to compare their coding, resolve discrepancies through discussion, and ensure consistent interpretation of the data. This collaborative process strengthened the trustworthiness of the findings. From there, major concepts were refined into themes through iterative team analysis. To maintain confidentiality, each participant was identified by an anonymous randomized numbering system, such as OMS2-01, meaning year 2 osteopathic medical student – number 1, with a randomized number assigned to each of the ten participants.

Trustworthiness

The researcher addressed trustworthiness by using the constructs of credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). Credibility was established in several ways during the study, including; (1) informing participants that the study is only interested in their personal experience and that there are no right or wrong answers during the interview; (2) participants could decline to answer a question if they didn't feel comfortable, and they could withdraw from the study at any time; and (3) The participants were given the opportunity to review and provide feedback on the data and findings (a process known

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as member checking) to ensure accuracy and credibility following data analysis. The study's transferability and ability to be generalized for a wider population were considered by providing a detailed description of the participants, laboratory environment, and data collection sessions. Various aspects of the study, such as research design, implementation, intervention design, data collection, and an introspective evaluation, were clearly described to address dependability in the research study. Confirmability was accounted for by an audit trail, including a detailed report on the research process, methodology, participant selection, intervention design, and data collection and analysis techniques.

Ethical Considerations

The research study was conducted after obtaining approval from the New Mexico State University Institutional Research Board (IRB# 2307070502) and a Site Letter for Research from the southwestern osteopathic medical school. Before beginning the study, every participant received and signed an informed consent document, which contained a written description of the study's purpose. It was emphasized that participation was completely voluntary, and participants had the right to withdraw at any point. The document also assured that all information collected during data collection would remain confidential.

Results

To address the research questions guiding this study, the researcher conducted a qualitative analysis of the NPT interviews to explore medical students' experiences with asynchronous training and their roles as near-peer teachers (NPTs). Three primary themes emerged from the data: workload**,** overcoming challenges, and asynchronous instruction**.** These themes directly reflect the lived experiences of NPTs as they navigated their training (RQ1), the challenges they encountered and the strategies they used to overcome them (RQ2), and their perceptions of instructional effectiveness (RQ3). The following section provides a detailed description of each theme and its corresponding subthemes, supported by quotes that illustrate the NPTs' perspectives in their own words.

Theme 1: Challenge of Time Commitments and Workload

The interviews with the NPTs emphasized the challenges of having to balance priorities in their life and their medical school workload while preparing for and teaching in the lab. As second-year medical students, the NPTs were concerned about balancing their courses, managing time due to other commitments, and starting to prepare for board exams.

> "I think the hardest part was making sure that I needed to do my own schoolwork and my own responsibilities before I started to do the near-peer teaching activities…The one challenge that sticks out in my mind would definitely be the time challenge." (OMS2-02)

> "I think there were certain times during this year that I felt like I was facing my own challenges, [such as] adjusting to balancing board preparation. . . And then also, like the demands of medical school and getting through classes, which don't always line up [from what they were teaching in lab]." (OMS2-05)

> "Medical school is very time demanding. Basically, all your free time goes towards it to be successful." (OMS2-08)

Theme 2: Overcoming Challenges

The NPTs described strategies they used to manage the challenges of their demanding schedules as second-year medical students. Two subthemes emerged related to overcoming the challenges of near-peer teaching: (1) prioritizing tasks and (2) implementing an organized time management plan. One effective strategy discussed by NPTs to manage additional responsibilities is to prioritize their coursework before focusing on teaching in the ultrasound lab.

> "I definitely have to prioritize my material [course work] before I can do their material [NPT instruction]." (OMS2-10)

Another effective strategy described by NPTs was developing a structured time management plan, which enabled them to efficiently balance their various academic and teaching responsibilities.

> "I got everything planned out and got my time managed and was able to not only review the materials but understand them and then obviously go into ultrasound and teach." (OMS2-02)

> "When I plan my studies, I tend to try to estimate how long things will take, and I try to leave the preparation for the ultrasound course and the near-peer teaching until pretty close to when I was going to go in." (OMS2-05)

> "I am really big on using a planner and organizing the way I'm going to do things." (OMS2-06)

Theme 3: Impact of Asynchronous Instruction

The NPTs highlighted several benefits of asynchronous instruction while also identifying areas that warrant further exploration regarding alternative methods of NPT training. Most participants affirmed findings from previous research, noting key advantages of asynchronous learning such as the ability to review material multiple times, progress at one's own pace, and accommodate the demanding schedules of medical students (Alzahrani et al., 2022; Habibpour et al., 2022). Additionally, some NPTs suggested that a blended approach, combining in-person and online instruction, might offer a more effective training model.

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The research study highlighted the benefits of asynchronous instruction for NPTs, along with areas requiring further analysis of NPT feedback.

> "I get to review the material when I want. If I want to do it between studying or if I want to do it late at night or early in the morning. I have the capability of changing my schedule." (OMS2-03)

> "I'm able to capture stuff better than if I was in person. If I miss something in person, I can't rewind it and go back or pause and take notes." (OMS2-06)

> "[With asynchronous learning] you can study at your own time, your own pace, go over things that you need to go over." (OMS2-08)

> "I like that [asynchronous learning] better from a time standpoint than an in-person lecture that you would have to go to because we are all so busy. Everyone has their own different schedules." (OMS2-10)

Some NPTs offered insights into areas for improvement within the asynchronous instructional program for near-peer teaching.

> "My one suggestion may be to add ten minutes before ultrasound [lab] to run through exactly what they [OMS-1 students] need to know. I think having a little session right before the class where individuals can ask questions to make sure that we're all on the same page so that we're not shocked by anything." (OMS2-03)

> "I still wish that there was a live presentation, like a live video or something like that at the beginning of ultrasound [lab] that still walked you through, like doing a quick little demo." (OMS2-04)

> "The see one, do one, teach one [model], I feel like would have helped a lot more than just the see one, teach one. That was kind of where the asynchronous part fell short." (OMS2-07)

Discussion

This study examined the positive impact of using online, asynchronous instruction of near-peer teachers in a medical school's ultrasound component of the human anatomy lab. The researcher created online asynchronous instruction modules based on Merrill's FPI. Based on the findings, medical students face various challenges as NPTs and use different strategies to overcome them. The study also found that systematically designed asynchronous instruction helped NPTs overcome challenges by giving students the flexibility to integrate the sessions into their study schedules.

NPTs reported that there were challenges with the time commitments of being a medical student and instruction to be a near-peer teacher. Consistent with previous studies, the results highlight concerns about the heavy workloads and time commitments faced by medical students who choose to participate in near-peer teaching (Kruskie et al., 2023). The NPTs shared that the time commitment of an increased workload during the second year of medical school can be overwhelming at times. This includes staying on top of their own coursework, starting to study for board exams, and being an NPT. These challenges can significantly impact the success of NPTs and may affect their overall medical education experience.

According to the results, the NPTs were able to overcome their perceived challenges by implementing effective strategies, along with the asynchronous instruction provided. The interviews revealed that the NPTs employed two approaches to address the challenges. The initial strategy involved prioritizing studying, coursework, and instruction as an NPT. Not surprisingly, as the semester progressed and the workload increased, the NPTs prioritized studying and coursework over near-peer teaching. The second strategy was to develop an organized and effective time management plan. This study aligns with previous research indicating that effective time management strategies lead to academic success and improved learning outcomes (Bickerdike et al., 2016; Alzahrani et al., 2022).

The research study highlighted the benefits of asynchronous instruction for NPTs, while also identifying areas where further analysis of their feedback is needed. NPT responses aligned with previous research, which emphasizes advantages such as the ability to learn at one's own pace, revisit course material and maintain a flexible schedule that suits the demands of medical students (Alzahrani et al., 2022; Habibpour et al., 2022; Vaudrey et al., 2025). The NPTs emphasized the value of accessing resources according to their individual schedules and workloads. This scheduling flexibility, along with the opportunity to review material as needed for deeper understanding, was noted as a key strength of asynchronous instruction. According to several NPTs, a blended approach that combines online instruction and in-person may offer the most effective learning experience. During interviews, participants suggested that incorporating a brief pre-lab demonstration or a synchronous session could help address questions and clarify expectations for the upcoming lab. In Figure 1, a proposed instructional design theory utilizing a hybrid model is shown. This model illustrates the inputs, processes/activities, and outputs of the current instructional design for medical students engaging in near-peer teaching. Under processes/activities, the synchronous portion of the diagram indicates where the hybrid component could be integrated into the instructional design model for instruction.

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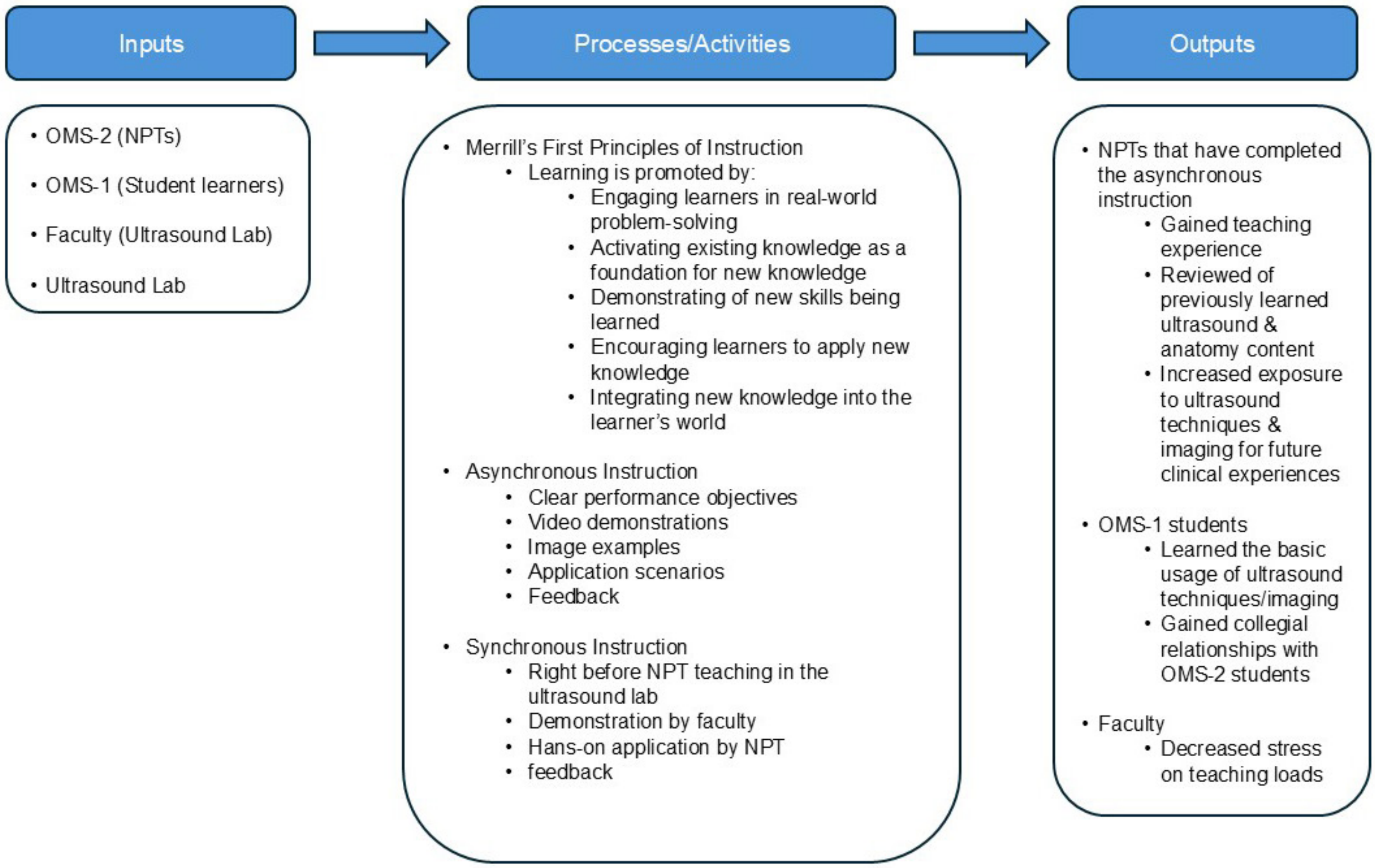

Figure 1: *Proposed Instructional Design Model for Near-Peer Instruction*

Based on the findings, it is important to consider the challenges that medical students face when systematically designing online asynchronous instruction, as well as recruiting future NPTs. Asynchronous instruction allows for flexible scheduling and helps individuals overcome the many time commitments of medical school. Furthermore, reviewing previously learned information, gaining more experience with ultrasound imaging, and providing instruction can all benefit the NPT in their future medical practice. Another recommendation from the findings that should be taken into consideration is the implementation of a hybrid model for NPT instruction. Conducting a brief, practical demonstration before teaching in the ultrasound lab, along with the asynchronous modules, could enhance the confidence, quality, and delivery of instruction provided by the NPTs. This could be an essential area to apply instructional design theory to the practice of medical education.

Conclusion

This study explores the experiences of second-year medical students participating in a near-peer teaching program, with a focus on the challenges they encounter, the strategies they employ to overcome them, and their experiences with asynchronous instruction in the context of ultrasound lab teaching. The findings indicate that NPTs face substantial challenges, particularly in managing their time and balancing academic workloads. While asynchronous instruction was perceived as beneficial in addressing some of these issues, further investigation is needed to determine whether a hybrid model, incorporating a brief pre-lab demonstration, might offer greater instructional effectiveness.

We believe the findings from this study on formalized online asynchronous instruction can inform other medical institutions in the development of their near-peer teaching programs. This approach may be particularly valuable for academic settings where NPTs have limited availability due to demanding schedules. Furthermore, the results may have broader applicability to other laboratory-based courses, such as gross anatomy or clinical skills training.

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The findings of this study are limited by the small sample size of medical students from a single private medical school in the southwestern region. It is important to note that these students were selected for the ultrasound segment of the human anatomy laboratory based on their application to the near-peer teaching program and their willingness to volunteer. Additionally, some data relied on self-reported information from participants, which may introduce bias.

Future research should expand to include multiple campuses and adopt longitudinal study designs to increase sample size and enhance the generalizability of findings related to near-peer teaching in medical schools. Additionally, further investigation into hybrid instructional models is warranted, combining the advantages of asynchronous learning with hands-on experiences that could provide NPTs with the opportunity to clarify questions and be better prepared for teaching their peers.

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Appendix 1. Interview Protocol

Title: *A Model for Training Medical School Students for Near-Peer Teaching*

Time of Interview:

Date:

Interviewer:

Interviewee:

Position of the Interviewee:

Thank you so much for agreeing to talk with me today. My name is ____________, and I am working with Dr. Kristopher Vaudrey. The goal of this study is to understand the effectiveness and efficiency of an asynchronous training program for near-peer teachers in a medical school. I am having these conversations with approximately 10 people. During today's interview, I will ask you a series of open-ended questions to learn more about your lived experiences focusing on the asynchronous training you received as a near-peer teacher in a medical school. The responses provided by you will be summarized along with others' responses. Our discussion will last approximately 30 to 45 minutes, but feel free to let me know whenever you may need a brief break or if you are unable to complete today's interview and need to schedule another day to complete the interview.

Additionally, with your permission, I will be audio recording today's conversation because I do not want to miss anything you say. For the recorded portion of our conversation, we will be on a first name basis, and we will not use names in any reports. What you say during our discussion is confidential.

Lastly, before we begin our discussion, I would like to go over some guidelines:

- *There are no right or wrong answers to these questions.*
- *I am interested in your thoughts, feelings, and lived experiences so please feel free to share your point of view, even if you don't think it's what I want to hear.*
- *If you do not feel comfortable answering a particular question, please let me know and we will move onto the next question.*
- *If you think we should know something that does not directly answer or fit with your response to a question, please don't hesitate to ask me about it or bring it up during our conversation. There may be important topics that we may have forgotten to ask about and your help is greatly appreciated.*

Do you have any questions about what to expect during the rest of our conversation today before we begin?

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Questions:

- To what extent did each of the following features of the training prepare you for near-peer teaching:
- How has the asynchronous training affected your ability to teach as a near-peer teacher?
- How do you feel the asynchronous training has affected your ability to use ultrasound in future medical practice?
- How has your knowledge from your first-year ultrasound instruction contributed to your abilities as a near-peer teacher?
- How adequately did demonstrations during asynchronous training prepare you for near-peer teaching?
- Describe how the application activities, including self-assessment questions in the asynchronous training, affected your near-peer teaching?
- Please reflect on and share your thoughts on how the asynchronous training may impact your abilities as a future physician.

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Comparing Draw-to-Learn and Traditional Lecture Methods for Knowledge Retention among Doctoral Physical Therapy Students

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Abstract

Graduate level education for Doctor of Physical Therapy (DPT) students may include several types of instructional methods, including passive learning through lecture and active learning using drawings or hands-on activities. Currently, there is limited research aimed at understanding what type of instructional methods are best for student learning and retention of knowledge. The purpose of this study was to investigate the effects of a drawing-to-learn activity during a classroom lecture versus a traditional classroom lecture on student retention of knowledge, as well as student satisfaction within an anatomy course in a DPT degree curriculum. Participants were randomly assigned to either a control group, which received a traditional lecture lesson or an experimental group, which received a drawing-to-learn lesson using a drawing template. Both lessons covered internal heart anatomy, consisting of the same structures and main points. Pre-lesson and post-lesson data for both groups were collected to assess immediate short-term student retention of knowledge, participant satisfaction, and feedback about the lesson. Both groups demonstrated significant ($p < 0.05$) gains in retention of knowledge. Between-group differences in gains in retention of knowledge were not statistically significant ($p > 0.05$). However, the experimental group reported greater satisfaction than the control group ($p < 0.05$). Thematic analysis of the qualitative data revealed three themes: Organization & Pace, Engagement & Interactivity, and Clarity & Reinforcement. Incorporation of drawing into lessons led to greater student satisfaction and similar learning outcomes when compared to traditional teaching methods. https://doi.org/10.21692/haps.2026.003

Key words: anatomy, drawing, drawing-to-learn, knowledge retention, physical therapy

Introduction

Finding the most effective pedagogical strategies and teaching methods is highly important to educators in a variety of educational settings. A common method of teaching, particularly in higher education, is passive learning. Some passive learning methods include in-person lectures and digital slide presentations. However, the findings of previous research suggest that active learning teaching methodologies, such as those utilizing drawing, are more effective than passive learning methods (Alsaid, 2016; Beach et al., 2023; Joewono et al., 2018; Murtonen et al., 2018).

Miller et al. (2013) conducted an investigation that compared traditional lectures to "engaging" lectures in a cohort of dentistry students enrolled in a physiology course. Traditional didactic lectures consisted of passive learning through exposure to content and minimal student interactions with each other during class time. Engaging lectures consisted of an active learning strategy involving 10–15 minutes of lecture followed by an activity that allowed students to actively apply the content to which they had just been exposed. Example activities included problems or prompts that required students to brainstorm outcomes, compare and contrast pathologies, match terminology and definitions, complete case studies, solve mathematical equations, draw Venn diagrams, think-pair-share activities, and write 1-minute papers. As this study demonstrated, a variety of active learning strategies can be implemented in the classroom involving drawing and non-drawing engagement strategies.

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While traditional lectures primarily rely on the auditory-verbal channel, the drawing-to-learn approach leverages the principles of the cognitive theory of multimedia learning to facilitate deeper encoding to memory. According to Mayer (2024), meaningful learning occurs when students engage in active processing and when classroom instruction aims to minimize extraneous processing, manage essential cognitive processing, and encourage generative processing. By transitioning from a passive recipient of information to an active creator, the student can commit more words and images to working and stored memory and mentally connect it with prior knowledge and other concepts. Lessons incorporating drawing with cognitive load theory in mind reinforce the mental representation and moderate the cognitive load by distributing the processing demands across both the visual and phonological subsystems of working memory (Sweller et al., 2011). Consequently, a drawing-to-learn activity may result in better learning outcomes and student retention of knowledge compared to traditional lecture-based instruction by fostering the construction of more robust mental schemas.

Assessing student retention of knowledge after passive or active learning activities is equally important. Retention of knowledge is the ability to preserve new information and can be considered as a foundational step in Bloom's taxonomy of learning following the processes of comprehending, applying, analyzing, synthesizing, and evaluating cognitive and psychomotor skills (Anderson & Krathwohl, 2001). Retention of knowledge can be assessed in a variety of ways. Two of the most common measures used are true-false questions and multiple-choice questions (Custers, 2010). Miller et al. (2013) found that student retention of knowledge (measured by unit and final examinations) was higher when instruction was provided by active teaching methods using engaging lectures as compared to traditional lectures employing passive learning.

One active learning teaching method entails students drawing an object(s) that visualizes a concept, sometimes referred to as "drawing-to-learn". In a study by Styn et al. (2022), medical students enrolled in a gross anatomy course read text and viewed illustrations about nerves of the arm, topography, area of sensory supply, and structures that are important for the pathway of the nerves. Afterward, students constructed a drawing about the text and illustrations pertaining to the nerves of the arm. Students were randomly assigned to either a group who constructed drawings using a digital tablet or a group who constructed drawings using paper. Student retention of knowledge was assessed using an examination. The results of Styn et al. (2022) indicated that both modes of drawing (tablet and paper) were equally effective with regard to student retention of knowledge. Although these findings suggested that drawing-to-learn is an effective active learning strategy, a limitation of the Styn et al. (2022) study is that students did not construct drawings during lecture and in a classroom environment, which is more reflective of many educational settings.

Although previous research suggests that drawing-to-learn is an effective active learning method, additional investigations are needed to determine if drawing-to-learn is effective in different learning environments and within different curricula within higher education. The research question was: Can a drawing-to-learn activity during a classroom lecture be more effective for student learning than a traditional classroom lecture alone in a gross anatomy course within a Doctor of Physical Therapy (DPT) curriculum? The research hypothesis was that a drawing-to-learn activity during a classroom lecture is more effective than a traditional classroom lecture. Thus, the purpose of this study was to investigate the effects of a drawing-to-learn activity during a classroom lecture versus a traditional classroom lecture on student retention of knowledge and student satisfaction.

Methods

Study Design and Procedures

This study was a randomized control trial conducted at the University of Central Arkansas (UCA) Department of Physical Therapy. Participants within the gross anatomy course in the DPT program at UCA were randomly assigned to either an experimental group or control group.

The experimental group participated in a classroom-based lecture during which the instructor drew lecture-related illustrations on a digital drawing monitor. The experimental group actively replicated the instructor's drawings based on a blank template (Figure 1) using either a paper copy with markers or a personal digital tablet during the lecture without any complimentary materials such as slides with words, figures, or a notes page. Each student in the experimental group was allowed to take any additional notes during lecture, as they preferred.

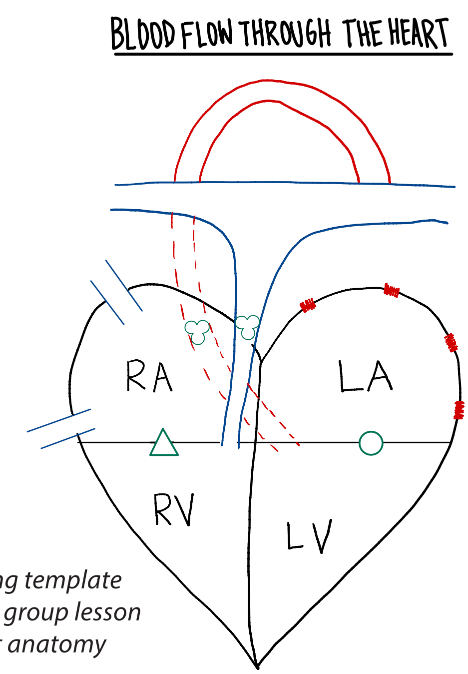

Figure 1. *Drawing template for experimental group lesson on internal heart anatomy*

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The control group participated in a separate classroom-based traditional lecture using digital slides with words and figures from an anatomy atlas. The instructor gave the same lecture that was given to the experimental group, except the instructor did not draw illustrations. The participants in the control group were all given copies of the digital slides. As in the case of the experimental group, the control group was allowed to take any additional notes during the lecture.

For both groups, a pre-lesson survey was given to assess student anatomy knowledge prior to the activity. Retention of knowledge outcomes data for both groups were collected using a post-lesson quiz after lecture sessions were complete.

Study Setting, Recruitment, and Participant Criteria

This study was approved by the institutional review board of UCA (IRB# 24-099) and conducted in the Physical Therapy Center on that campus. Informed consent was obtained from all participants. Participants were recruited from first-year DPT students enrolled in the fall 2024 gross anatomy course. Recruitment occurred through verbal announcements by the lesson instructor who is also the principal investigator of this study. To reduce coercion and expectancy effects, potential participants were verbally informed that participation in the study was voluntary. Participants also received a digital copy of an informed consent letter (approved by the UCA institutional review board) via email and were given an opportunity to ask questions about the study prior to study initiation.

During recruitment, students were verbally informed that a possible benefit of participation in the study would be more familiarity with upcoming course content on the same lesson topic of the study (internal heart anatomy) and that participants would receive 3 bonus points in the course. The possibility of more familiarity with upcoming course content on internal heart anatomy was only a potential benefit and the 3 bonus points were only approximately 0.27% of the total course points (1120) and, therefore, considered to be reasonable compensation and not coercion. Quiz scores were used only for the purpose of the study and were not included in the calculation of student course grades. Participant demographic information (e.g. age, sex, race/ethnicity, and year of school) were collected using an electronic form.

Prior Knowledge and Retention of Knowledge

Participants' perceptions of their prior knowledge and actual prior knowledge surrounding the lesson topic, blood flow through the heart, were recorded using a pre-lesson survey. The survey asked participants to rate their prior knowledge of the topic on a Likert-like scale from 1 (very low) to 5 (very high). Participants first answered dichotomous yes or no questions regarding their prior knowledge of blood flow through the heart, then proceeded to answer multiple choice questions linked to the dichotomous questions to determine if their perception of their prior knowledge correlated with their actual prior knowledge.

Retention of knowledge was measured using a post-lesson quiz containing the same five-item multiple-choice questions from the pre-lesson quiz. To assess retention of knowledge for the control and experimental groups, the five-item multiple-choice quiz was administered immediately after the lessons. Retention of knowledge was scored based on the number of correct responses on the post-lesson quiz. Pre-lesson survey questions that assessed student perceptions of their prior knowledge, actual prior knowledge, and retention of knowledge can be found in Table 1.

Pre-lesson perceptions of prior knowledge questions	Pre-lesson actual prior knowledge and retention of knowledge questions
Question format: Dichotomous Yes or No	Question format: Multiple choice A-D
Do you know which structures of the heart contain deoxygenated blood?	Which of the following structures of the heart contains deoxygenated blood?
Do you know what structure blood enters after leaving the lungs?	After leaving the lungs, blood re-enters the heart through which of the following structures?
Do you know what structure blood passes through before delivering oxygenated blood to the body?	Prior to delivering richly oxygenated blood to the body, blood must pass from the left ventricle through which structure?
Do you know where blood flows after passing into the superior and inferior vena cavae?	Blood flows from the superior and inferior vena cavae to the ________.
Do you know what clinical implications result from a defect in the walls between the atria or ventricles?	When the foramen ovale does not close to become the fossa ovalis, patients can experience symptoms of fatigue due to:

***Table 1**. Pre-lesson survey questions*

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Student Satisfaction

A secondary outcome was student satisfaction with the lesson. At the end of the lesson, students within the experimental and control groups rated their level of satisfaction with the method of teaching on the post-lesson survey using a Likert-like scale from 0 (not satisfied) to 10 (very satisfied). Open-response questions about the learning activity were included that explored what the participants liked most about the lecture and what they thought could make the activity more helpful to their learning.

Randomization and Participant Code Number Assignment

Study participants were randomly assigned to either the experimental or control group using a random number generator. A list of participant names was entered into a spreadsheet software program that then randomly generated a number between 0 and 1 for each participant. Participants were ranked lowest to highest based on their randomly assigned number and were divided in half to be assigned the number 1 (lower half) or 2 (upper half) for the group they were assigned. Participants who were assigned the number 1 or the number 2 were assigned to the control group and experimental group, respectively. A participant code number was pre-assigned to each participant on their pre-lesson survey at the start of their lesson. The same code number was used for each respective participant on the post-lesson survey. These code numbers were used to validate paired data and de-identify participants. A master coding list was created to match participant names to their respective participant code numbers, which was used for data analysis and destroyed at completion of the study.

Data Analyses

Participant characteristics data were reported as means, standard deviations, and counts, as appropriate. Retention of knowledge was operationalized as the number of correct responses on the post-lesson five-item multiple-choice quiz. Baseline equivalence between the experimental (drawing-to-learn) and control (traditional lecture) groups on pre-lesson quiz scores and self-reported prior knowledge ratings was examined using independent-samples t tests. Within each group, pre- to post-lesson changes in quiz scores were evaluated using paired-samples t tests. To compare post-lesson quiz performance between instructional methods while adjusting for potential baseline differences, an analysis of covariance (ANCOVA) was conducted with post-quiz score as the dependent variable, instructional group (drawing-to-learn vs traditional) as the fixed factor, and pre-quiz score as a covariate. Partial eta squared (ηp^2) was calculated as an index of effect size for the ANCOVA. For additional interpretability, gain scores (post-quiz minus pre-quiz) were computed for each participant and compared between groups with independent-samples t tests; standardized mean differences are reported as Hedges g. Group differences in satisfaction ratings were also examined using independent-samples t tests with Hedges g as the effect size. Exploratory Pearson correlations were used to describe the associations among self-reported prior knowledge, pre- and post-quiz scores, gain scores, and satisfaction. Statistical significance was set a priori at $\alpha = 0.05$. Descriptive statistics for all quantitative variables are presented in Table 2.

Qualitative Analysis

Thematic analysis was used to analyze responses to open-ended questions on the post-lesson surveys (Ahmed et al., 2025). Thematic analysis was most applicable for analysis of qualitative survey results because of its flexible application and the ability of the researchers to uphold reflexivity. Braun and Clark's thematic analysis was used in six steps: 1) familiarization with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, and 6) writing the report (Ahmed et al., 2025).

Two separate researchers with experience in performing these six phases of thematic analysis first separately created codes from the raw data and grouped codes into themes (Ahmed et al., 2025). One researcher performed steps 1-4 using a color-coding scheme and finding word matches and associations, while the other researcher utilized artificial intelligence for building a codebook (Bryda & Sadowski, 2024). Each researcher used an individual codebook with an audit trail to ensure credibility and reflexivity. After individually coding and creating initial themes, the two researchers met together to discuss their findings, review themes for coherence and relevance, and name final themes with exemplar participant quotes from the data for each theme. During steps 4-6 of the thematic analysis, both researchers compared their initial themes for completeness and to ensure final themes were reported to reflect responses from all participants.

Results

A total of 57 DPT students were enrolled in this study. Twenty-seven students were randomly assigned to the experimental (drawing-to-learn) group (males = 9, females = 18, mean age = 22.7 years [standard deviation = 2.2]) and 30 students were randomly assigned to the control (traditional lecture) group (males = 7, females = 22, non-binary = 1, mean age = 22.4 years [standard deviation = 3.2]). Baseline comparisons indicated that the drawing-to-learn and traditional lecture groups were similar on both pre-lesson quiz scores and self-reported prior knowledge of blood flow through the heart; between-group differences on these measures were small and not statistically significant.

Within the drawing group, mean quiz scores increased from 1.70 correct responses at pre-lesson to 4.37 at post-lesson, and within the traditional lecture group from 1.87 to 4.33, indicating substantial learning during the lesson in both groups. When post-lesson quiz scores were compared between groups using ANCOVA with pre-lesson quiz scores

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entered as a covariate, the main effect of instructional group was not statistically significant ($F(1,54) = 0.14$, $p = 0.72$, partial $\eta^2 = 0.002$). Consistent with this finding, the between-group difference in gain scores (post-lesson minus pre-lesson quiz) was small and not statistically significant (mean difference [drawing-to-learn – traditional] = 0.20 points, 95% confidence interval –0.50 to 0.90, p = 0.57, Hedges g = 0.15). Collectively, these findings indicate that the drawing-based and traditional lecture formats produced comparable short-term retention of internal heart anatomy knowledge.

Students within the drawing-to-learn group rated their satisfaction with the activity higher (mean = 9.3/10) than those in the traditional lecture group (mean = 8.1/10). This 1.16-point difference on the 0–10 satisfaction scale was statistically significant (95% confidence interval 0.41 to 1.91, $p = 0.003$) and corresponded to a large, standardized effect (Hedges g = 0.80), indicating that students found the drawing-based lesson substantially more satisfying than the traditional slide-based lecture. In practical terms, this pattern suggests that instructors who utilize digital inking in their lessons or inviting students to draw alongside the instructor may not change immediate quiz scores, but meaningfully enhance how enjoyable, engaging, and helpful the lesson feels, which may in turn support student motivation and willingness to persist with challenging anatomy content.

All 57 participants responded to two open-response post-lesson survey questions, resulting in qualitative analysis of 114 open-ended responses. Thematic analysis of open-ended survey questions from the control and experimental groups resulted in three themes: Organization & Pace, Engagement & Interactivity, and Clarity & Reinforcement.

The first theme, Organization & Pace, was created from codes such as "step-by-step", "clear", "concise", and others involving how quickly or slowly the participant thought the lesson progressed or how it could be improved. Though not all participants agreed on whether they felt the lesson was too short or too long, many participants from both groups mentioned that the organization of the lesson and the timing of the lesson was helpful to their learning. Codes from the second theme, Engagement & Interactivity, were mentioned by the experimental group (drawing-to-learn lecture) as

Variable	Drawing-to-learn group			Traditional group		
	n	mean	SD	n	mean	SD
Self-reported prior knowledge (1–5)	27	2.56	0.70	30	2.82	0.84
Pre-lesson quiz score (# correct)	27	1.70	1.35	30	1.87	1.46
Post-lesson quiz score (# correct)	27	4.37	0.88	30	4.33	1.06
Gain score (post – pre)	27	2.67	1.27	30	2.47	1.36
Satisfaction rating (0–10)	27	9.26	0.98	30	8.10	1.75

Table 2. *Descriptive statistics for prior knowledge, quiz performance, and satisfaction by instructional group*

	Self-reported prior knowledge	Pre-lesson quiz score	Post-lesson quiz score	Gain score (post – pre)	Satisfaction rating
Self-reported prior knowledge	1.00	0.37	0.13	-0.30	0.09
Pre-lesson quiz score	0.37	1.00	0.44	-0.74	-0.02
Post-lesson quiz score	0.13	0.44	1.00	0.28	0.16
Gain score (post – pre)	-0.30	-0.74	0.28	1.00	0.13
Satisfaction rating	0.09	-0.02	0.16	0.13	1.00

Table 3. *Pearson correlation matrix for prior knowledge, quiz performance, and satisfaction*

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things they enjoyed about the lecture and by the control group (traditional lecture) as things that would have been more helpful to their learning. Interactivity & Engagement in a lesson were important to both participant groups as part of their learning.

The third theme, Clarity & Reinforcement, blended with the first theme of Organization & Pace as participants from both groups noted their appreciation for clear identification of important anatomical structures organized in a step-by-step manner to help students visualize using either a figure or drawing, and that information was repeated often. Many participants also mentioned they enjoyed learning the "try before you buy it" saying for remembering the tricuspid valve comes before the bicuspid valve, indicating that useful ways of remembering information incorporated into the lesson can help with reinforcement. Individual codes leading to the creation of themes along with participant quotes from the data can be found in Table 4.

Discussion

To our knowledge, this study is the first investigation comparing the effect of a drawing-to-learn activity versus a traditional lecture on retention of knowledge on internal heart anatomy by DPT students participating in a gross anatomy course. The research hypothesis was that a drawing-to-learn activity would be more effective than a traditional classroom lecture. The findings of this study suggest that the drawing-to-learn activity was as effective as a traditional lecture in retention of knowledge in internal heart anatomy. However, DPT students who participated in the drawing-to-learn activity were more satisfied with their learning experience than the DPT students who participated in the traditional lecture.

A possible explanation as to why similar learning outcomes occurred between the DPT students who participated in the drawing-to-learn activity and the DPT students who participated in the traditional lecture is the pace and time of

Code	Participant Quote Examples	Theme
• Concise • Short and sweet • A little fast • More time • A little slower • Step-by-step • Easy to organize	• It was short, clear and concise. [The instructor] repeated things a lot which helped reinforce it. • I learn much better through drawing + will usually turn my notes into something like this! It was just a little fast but I think it was me being a perfectionist that took too long.	Organization & Pace
• Pictures, diagrams, figures, images • Engaged • Interactive, interaction	• I think that having the PowerPoint be more interactive in some way could help with long term retention.. • Incorporating textbook/real images with the drawing to see the real thing occurring that we are drawing • I liked how engaged I felt during the activity. I was interested + followed along the whole time.	Engagement & Interactivity
• Repeated, restated • Clear, step-by-step • Visualize, diagram, figures, drawing • Helpful ways of remembering concepts	• I enjoyed looking at the images + having connections like "try it before you buy it" • I liked that the activity was very clear (step-by-step) and that the structures and overall flow was repeated several times.	Clarity & Reinforcement

Table 4. *Thematic analysis coding table*

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the lectures. Both lectures were approximately 20 minutes long. Learning activities of shorter durations are considered to fall under a pedagogical approach often referred to as microlearning. Previous research indicates that microlearning can have a positive effect on student learning and other educational outcomes (De Gagne et al., 2019). Also, both learning activities (drawing-to-learn and traditional lecture) were constructed to align with the same, specific learning objectives. Constructive alignment is an instructional design approach that starts with establishment of learning objectives followed by the selection of appropriate teaching methods that optimally allow students to achieve the learning objectives (Biggs, 1996). Thus, one can infer that both learning activities were equally effective in part because the activities were constructed to match specific learning objectives.

Key findings for previous research on using drawing for knowledge retention compared to traditional lecture are inconsistent. The results of one study showed that students who received a drawing-based neuroanatomy lecture had significantly higher scores on a post-lesson quiz than students who received a more traditional non-drawing-based lecture (Alsaid, 2016). Some studies showed the use of drawing-based learning activities to result in a higher retention of knowledge compared to traditional lectures (Alsaid, 2016; Beach et al. 2023; Joewono et al., 2018; Murtonen et al., 2018; Pickering, 2017; Na et al., 2022). Another study found no statistically significant differences between two different drawing lesson groups (Alsaid & Bertrand, 2016).

The results of our study add to the knowledge favoring using drawing-based lecture methods as a feasible approach within DPT education. Our findings also support that drawing-based lessons lead to equivalent student retention of knowledge and higher student satisfaction when compared to traditional lectures. Higher student satisfaction ratings for the drawing-to-learn lesson also may guide educators in implementing lessons that lead to higher student engagement, while still providing a clear and organized lesson that reinforces topics for complex anatomy. Though educators must consider knowledge retention when weighing whether or not to use a drawing-to-learn activity, the novelty of these activities while maintaining the same lesson time, flow, and objectives may provide students with encouragement to actively participate during the lesson and make their time in the classroom more productive and enjoyable.

Many students in higher education utilize digital technology (for example, tablets) for drawing as opposed to paper copies. Styn et al. (2022) found that using a tablet for learning through drawing activities was not significantly different from using paper and markers or summarizing a lesson. However, students who drew using a tablet for the activity reported the activity to be more motivating and enjoyable (Styn et al. 2022). While our study did not investigate student motivation, our study findings agree that even when knowledge retention is not significantly different between groups, drawing can provide engagement and interactivity within an anatomy lesson that boosts student satisfaction compared to traditional slides with text and figures.

The experimental group (draw-to-learn activity group) was allowed to choose the drawing modality (paper with markers or their personal digital tablet). Some students typically used paper in their classes to take notes, while others frequently used their personal digital tablet. If student participants were required to use a specific drawing modality, doing so may have been a confounding variable. For example, a student who is unfamiliar with the use and operation of a digital tablet may experience challenges in using the tablet for drawing purposes, while another student who regularly uses a digital tablet may be very familiar with its drawing functions. By allowing students to choose the drawing modality, a possible confounding variable was controlled.

Zhang and Fiorella (2021) found that creating drawings from visuals or diagrams can improve comprehension when compared to studying the visuals alone. However, it does take more time and cognitive effort from the student. Incorporating templates for drawings within a lesson may give students a guide for studying and reduce the cognitive effort for retention of knowledge after the lesson is over. Adkins et al. (2023) found that drawing improved clinical preparedness, visual-spatial understanding, and peer-based communication; participants reported better understanding of anatomy and pathology. Though the results of our study cannot confirm these findings, this is important to investigate in further research as DPT students are expected to cultivate each of these characteristics before interacting with patients, peers, and caregivers in a clinical setting.

As in the case of all randomized controlled trials that include pedagogical interventions, readers should consider all aspects of the drawing-to-learn activity and traditional classroom lecture. The traditional classroom lecture group received what was considered to be traditional delivery of a lecture (classroom-based lecture using digital slides along with copies of the slides and no student interactions with each other). The intervention (as a whole) for the traditional classroom lecture group was designed to replicate typical practice when providing instruction during a traditional didactic lecture. Common practice for the student participants in this study was to receive a traditional lecture using digital slides as well as copies of the slides. The traditional classroom lecture intervention was intended to replicate typical teaching methods with which the students were familiar. In contrast, the drawing-to-learn activity group participated in a drawing activity that did not include the use of digital slides nor copies of slides. Readers are encouraged to consider the totality of the interventions when interpreting the results of this investigation.

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This study has several limitations. It was conducted within a single anatomy course at a single university, so results may not be generalizable to all classes within higher education. It was also conducted within a graduate physical therapy program, so the effects of drawing-based learning on retention of knowledge in other health-care fields and within other foundational courses may not be equivalent. This research was conducted within a single learning session. The most effective teaching strategy for long-term retention of student knowledge was not incorporated into the study design. Another limitation of this investigation was the constraints of a five-item post-quiz as a measure of knowledge retention. A five-item quiz is inherently prone to measurement error. An assessment with a small number of items may not have an adequate level of internal consistency, meaning assessment items that are intended to measure the same learning construct may not be doing so. The likelihood of an assessment having acceptable internal consistency (reliability) improves when using a larger number of assessment items. A five-item quiz may also be limited by ceiling effects. Finally, when interpreting the results of this study, readers should consider that only immediate (short-term) effects on retention of knowledge were examined. Suggestions for future research include exploring traditional lecture versus drawing-based lectures within other undergraduate and graduate foundational sciences courses. Future research focusing on student learning outcomes, including retention of knowledge and application of this knowledge within a clinical setting, is recommended.

In conclusion, this randomized controlled trial is the first investigation comparing the effect of a drawing-to-learn activity versus a traditional lecture on retention of knowledge on internal heart anatomy by DPT students. The findings of this study suggest that the drawing-to-learn activity and traditional lecture had similar outcomes in student retention of knowledge. However, DPT students who participated in the drawing-to-learn activity were more satisfied with their learning experience than the DPT students who participated in the traditional lecture. Based on the results of this investigation, educators can make an evidence-informed choice to incorporate a drawing-to-learn pedagogical approach when teaching foundational anatomy content such as internal heart anatomy. The researchers of this study plan to continue to implement drawing-to-learn activities within the DPT gross anatomy course beyond heart anatomy using current literature, evidence-guided practice, and student feedback in creating the best instructional methods for student learning and engagement.

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Enhancing Anatomy Learning through Drawing: A Comparative Study of Instructional Methods in Anatomy and Physiology

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Abstract

Traditional lecture-based instruction in undergraduate anatomy and physiology (A&P) courses often emphasizes memorization over conceptual understanding, which can hinder student engagement and retention. This quasi-experimental mixed-method study explored the impact of guided drawing as a learning tool during the digestive system unit in a Human A&P II course at a regional University in southwest Florida. Ninety-one students were divided into two groups: a drawing group (n = 45) and a lecture-only group (n = 46). The drawing group participated in structured visual activities designed to enhance spatial reasoning and comprehension. Quantitative data from two quizzes and final course grades showed no statistically significant differences in performance between groups based on Kruskal-Wallis and Mann-Whitney U tests. However, 88% of students in the drawing group reported improved understanding, and 70% noted increased engagement. A strong positive correlation emerged between perceived learning benefit and perceived academic performance ($r = 0.811$, $p < 0.001$), even though this was not reflected in course grades. Thematic analysis of qualitative feedback highlighted guided drawing's role in improving visualization, memory retention, and focus. While assessment scores did not show significant differences and academic benefit, the findings suggest that students perceive guided drawing as a valuable pedagogical strategy that supports student engagement in anatomy education. Further study is needed to assess long-term effects. https://doi.org/10.21692/haps.2026.004

Key words: anatomy and physiology education, drawing-based learning, student engagement, active learning strategies

Introduction

Undergraduate science courses, particularly Anatomy and Physiology (A&P), require students to absorb and retain large volumes of complex information within one or two semesters. Traditional lecture-based instruction emphasizing memorization has long dominated classroom teaching (Crawford & Parsell, 2025). However, emerging research suggests that this method alone may not fully support long-term retention or the meaningful application of knowledge in complex disciplines like A&P (Crawford & Parsell, 2025). In response, educators are increasingly exploring active learning strategies designed to foster deeper understanding, retention, engagement, and student confidence.

One particularly promising approach is the integration of drawing into science education, especially in anatomy courses, where visualizing spatial relationships and structural details is beneficial. The act of drawing requires students to slow down, process information more deeply, and translate abstract content into concrete visual representations (Quillin & Thomas, 2015). This multisensory engagement has been shown to enhance retention, conceptual understanding, and metacognitive awareness (Quillin & Thomas, 2015; Wammes et al., 2016; Wu & Rau, 2019).

Although initial research on the "drawing effect" was not discipline-specific, Wammes and colleagues (2016) first established that drawing significantly improves recall compared to writing or verbal rehearsal alone. Building on this work, Fernandes et al. (2018) proposed the Integrated-Trace Hypothesis, which suggests that drawing strengthens memory by activating visual, motor, and semantic pathways. This cognitive foundation has since informed a growing body of research applying the benefits of drawing more directly to learning in the anatomical sciences (Bozdağ & Gürses, 2025; Greene, 2018; Joewono et al., 2018; Martínez et al., 2025; Poddar et al., 2025; Reid et al., 2019).

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Importantly, drawing has been positioned, not merely as a tool for memory retention, but as a core skill in scientific thinking and reasoning (Quillin & Thomas, 2015; Tytler et al., 2019). Quillin and Thomas (2015) argued that drawing should be explicitly taught to support model-based reasoning in biology, enabling students to visualize complex systems and engage more deeply in scientific inquiry. Similarly, Tytler et al. (2019) highlighted drawing as a key element of reasoning in science classrooms, emphasizing its role in supporting multimodal meaning-making. Through drawing, students can bridge abstract concepts with concrete representations and work collaboratively to deepen their grasp of scientific ideas.

Within anatomy education specifically, several studies have demonstrated the effectiveness of drawing for improving learning outcomes. Greene (2018) implemented progressive drawing exercises, in which students built anatomical relationships step-by-step, and found that this method promoted metacognition, visual clarity, and a holistic understanding of anatomical structures. Joewono et al. (2018) found that medical students who engaged in musculoskeletal drawing tasks achieved higher comprehension scores compared to those in lecture-only environments. Reid et al. (2019) further advanced this idea by coupling haptics, specifically touch, with drawing, showing that multisensory engagement enriched students' spatial reasoning and memory of anatomical content.

Recent research by Bozdağ and Gürses (2025) demonstrated that artistic anatomy lectures significantly enhanced medical students' visual memory, observational skills, and understanding of anatomy. Over 90% of students reported that the integration of art and anatomy deepened their learning, improved their clinical observation skills, and fostered analytical thinking. Similarly, Poddar et al. (2025) investigated veterinary students' responses to drawing skills in anatomy education, finding that students perceived drawing as essential for retaining knowledge, explaining complex topics easily, and enhancing their learning in both theoretical and practical assessments. Likewise, Martínez et al. (2025) found that structured drawing workshops in a skull anatomy course significantly improved students' knowledge, spatial reasoning, and attention to detail.

Complementing these applied studies, research has explored the learning environments under which drawing is most effective. Fiorella and Zhang (2018) emphasized that drawing supports active learning and generative processing but cautioned that its benefits depend on appropriate scaffolding and guidance. Without sufficient instructional support, drawing tasks can overwhelm students or result in misconceptions and frustration. Building on this, Wu and Rau (2019) highlighted the cognitive processes that drawing can enhance, such as integrating new information into existing knowledge structures and developing self-regulatory skills like monitoring one's own understanding. Because drawing prompts learners to pause, reflect, and make deliberate decisions about how to represent their knowledge, Wu and Rau underscored the importance of thoughtful instructional design to ensure students gain the full benefits of the process.

Beyond its cognitive benefits, drawing has also been shown to enhance communication skills and clinical reasoning. Liou et al. (2014) demonstrated that clinical sketching workshops improved medical students' ability to clarify anatomical relationships and visually communicate complex procedures. Lyon et al. (2013) further found that collaborative drawing exercises enhanced students' observational skills and encouraged them to make meaningful connections between the process of drawing and the cognitive steps involved in clinical diagnosis. Similarly, Thompson and co-researchers (2010) reported that integrating mandatory creative work into the undergraduate medical curriculum encouraged students to engage more deeply with clinical uncertainty, improved their expressive abilities, and developed empathy through reflective and imaginative thinking. Finally, interdisciplinary teaching approaches that combine drawing with reading and discussion have shown promise in supporting both learning and student confidence in undergraduate anatomy and physiology. Weiss et al. (2024) implemented a curriculum integrating medical literature, anatomical instruction, and drawing exercises. Students reported significantly increased confidence in their anatomical knowledge and a more meaningful learning experience. Qualitative feedback emphasized the value of drawing for reinforcing content, enhancing engagement, and creating a supportive classroom environment.

Collectively, this body of research positions drawing not only as a tool for memorization but as a meaningful method of constructing and communicating scientific knowledge. When thoughtfully integrated into anatomy education, drawing provides students with a creative, multisensory approach to mastering complex content, ultimately transforming traditional science instruction into a more interactive, reflective, and memorable learning experience.

To date, no studies have specifically investigated the impact of instructor guided drawing in undergraduate A&P II courses. This represents a gap in the literature. Therefore, this study investigated whether integrating guided drawing exercises into the digestive system unit of an undergraduate A&P II lecture course at a regional comprehensive university in southwest Florida enhanced student performance and engagement compared to traditional lecture methods. At this institution, Human A&P II is a lower level (typically taken in the second year) gateway course to enter upper-level exercise science, nursing, and most health science programs. The course follows the Human Anatomy and Physiology Society's (HAPS) national guidelines, which emphasize mastery of structure and function relationships, physiological processes, and clinical applications. Instruction is traditionally delivered through instructor-led PowerPoint lectures supplemented with textbook readings and occasional demonstrations. The expected outcomes include accurate recall of anatomical structures, comprehension of physiological mechanisms, and

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the ability to apply this knowledge to clinical contexts. While innovative strategies such as active learning and problem-solving activities are encouraged across the curriculum, implementation varies by instructor. For this specific unit, "traditional lecture" refers to instructor-centered delivery without structured student drawing or other visual learning interventions. Specifically, the study aimed to assess short-term learning outcomes, overall course performance, and student perceptions of drawing as a learning strategy.

Materials and Methods

Study Design and Context

This quasi-experimental mixed-method study was conducted at a regional comprehensive State university in Southwest Florida, USA. The intervention took place in Human A&P II, the second course in a two-semester sequence primarily serving health science majors, including nursing, exercise science, physical therapy, and occupational therapy students.

Participants

Undergraduate students enrolled in two sections of the same Human A&P II 3-credit course, taught by the same instructor, were included in this study (Figure 1). There were no exclusion criteria; all students registered for these sections were eligible to participate. Students self-registered for their courses through the university's standard enrollment system, and assignment to the drawing or non-drawing group was therefore determined by section enrollment rather than by researcher allocation. The two course sections were comparable in size and demographic distribution. One section consisted of 45 students (40 female, 5 male), while the other included 46 students (41 female, 5 male). Because students self-registered across both sections, the natural distribution of students across sections resulted in similar demographic and academic backgrounds. Participation in the guided drawing activities was incorporated into the normal classroom instruction for one section, while the other section received lecture-based instruction without guided drawing. Completion of the post-intervention survey was voluntary for the intervention group.

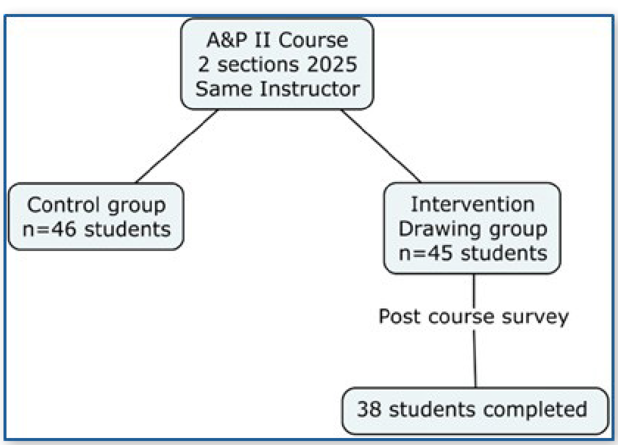

Figure 1. *Study flow chart.*

Intervention and Control Groups

Students were enrolled in two instructional groups, both taught by the same instructor (V.W.). The instructor holds an MD degree with a specialization in medical illustration and has more than 20 years of teaching experience.

The drawing group (intervention; n = 45) engaged in guided drawing exercises throughout the entire class period during the digestive system unit. Instead of receiving a traditional lecture, students participated in structured drawing tasks for the full duration of the scheduled session. These guided drawing activities were designed to reinforce digestive anatomy and physiology concepts and replaced, rather than supplemented, standard lecture time. Each drawing was presented as a simple line illustration projected via PowerPoint, constructed step by step until the complete image emerged, with color added at the final stage for clarity. Based on personal preference, students created their drawings at their desks using either an iPad or using traditional art supplies. Throughout the drawing sessions, discussion of form and function was integrated, highlighting anatomical structures alongside their physiological roles to reinforce conceptual understanding. Completed drawings were submitted via Canvas (the online learning management system used to organize and deliver all course content) for review.

The non-drawing group (control; n=46) received traditional lecture delivered through instructor-led PowerPoint presentations that included text and relevant images/diagrams. Instruction primarily consisted of instructor presentation and explanation of the material. No structured active-learning activities (e.g., diagram labeling exercises, worksheets, group work) were incorporated into the control sessions beyond standard lecture-based questioning. Both groups attended separate three-hour weekly lecture sessions during the Spring 2025 semester.

Data Collection and Instruments

Data was collected through Canvas at the end of the digestive system unit using an "instructor created" non validated seven-question survey assignment as part of the course material.

1. *Did you find drawing via guided medical illustrations helpful (valuable) to your learning of this content? (Y/N question)*
2. *Why or why not? (Open-ended question)*
3. *How did drawing compare to other study methods you have used for learning anatomy (ex. reading textbooks, watching videos, oral lecture, etc.)? (Open-ended question)*
4. *Describe how well you feel you retained the names/locations of anatomical structures after drawing compared to before the activity. Use a scale from 1-10 (1 being you feel as though you learned nothing, 10 being you remembered everything. (Number response and opportunity to provide additional feedback)*

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5. *What challenges did you encounter while using drawing as a study method for anatomy? (Open-ended question)*
6. *Do you feel that your performances in assessments (lecture quiz/lab quiz) improved as a result of drawing? (Y/N question)*
7. *For future drawing activities, what suggestions do you have for improving the use of drawing in lecture? Should it have been made simpler? More challenging? Faster in pace? Slower?... (Open-ended question)*

The survey assessed student perceptions of drawing as a learning tool, including items on engagement, confidence, understanding of anatomical relationships, and perceived effectiveness compared to lectures. Students in the drawing group received two extra credit points for completing the survey and submitting their drawings. Of the 45 students in the drawing group, 38 completed the survey, representing an 84.4% response rate.

In addition to the survey, all students completed two quizzes to assess immediate content retention. A 10-point multiple-choice quiz was administered immediately following the lecture in both groups. Subsequently, students attended their laboratory class session, which provided additional instruction with a focus on digestive physiology. Immediately following the laboratory class, all students completed a 20-point multiple-choice quiz.

Ethical Considerations

This project was approved by the IRB Board of Florida Gulf Coast University (RB #2023-41), and informed consent was obtained from all participants. Participation in the survey was voluntary, and students were informed that their responses would remain confidential and would not impact their course grades aside from the extra credit offered for completion.

Drawing Instruction

The primary author (VW) designed six simple, step-by-step guided drawings covering major anatomical aspects of the digestive system using Adobe Photoshop. The first drawing (Figure 2) demonstrated a segment of the digestive system. The second focused on the large intestine, rectum, and anus (Figure 3). The third depicted a cross-section of the large intestine, illustrating its four tunics (Figure 4). The fourth drawing covered the liver and gallbladder (Figure 5) while the fifth focused on the pancreas and surrounding organs (Figure 6). The final guided drawing (Figure 7) illustrated the stomach.

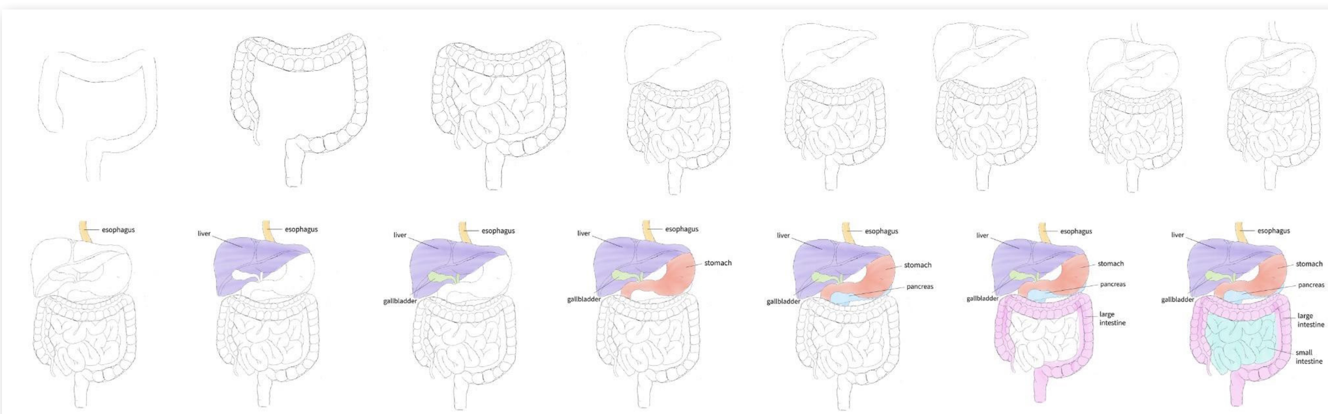

Figure 2. *Step-by-step drawings of part of the gastrointestinal tract.*

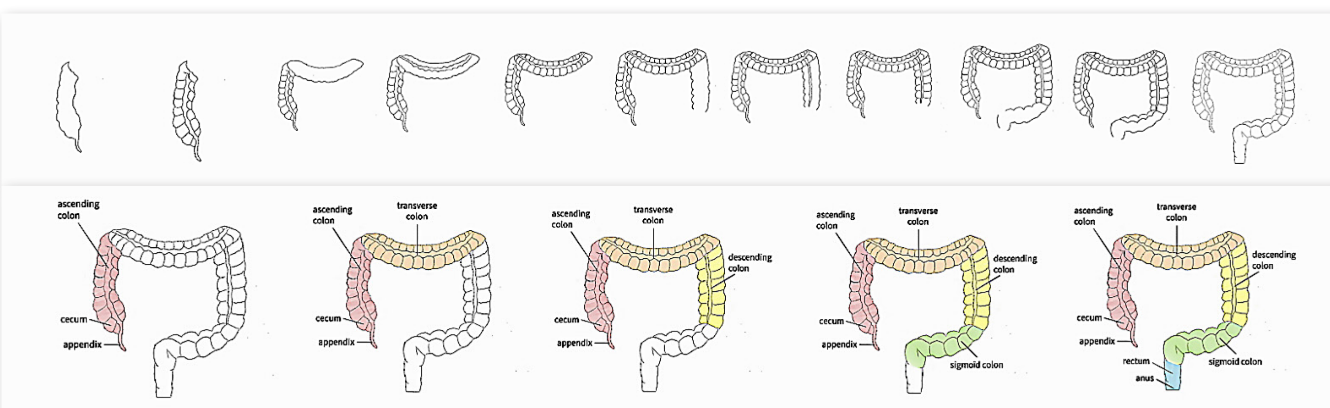

Figure 3. *Step-by-step drawings of the large intestine, rectum, and anus.*

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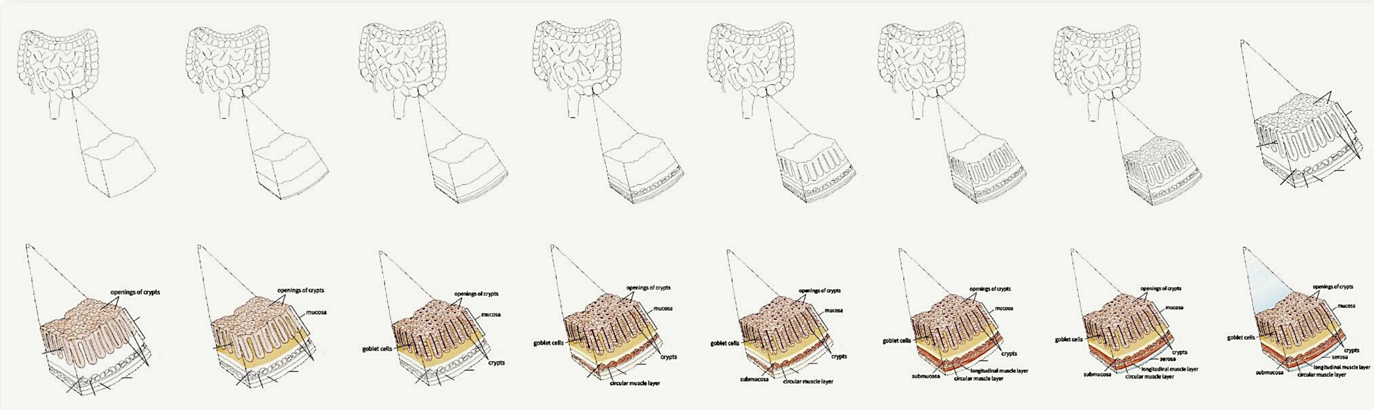

Figure 4. *Step-by-step drawings of the of intestine and its four tunics.*

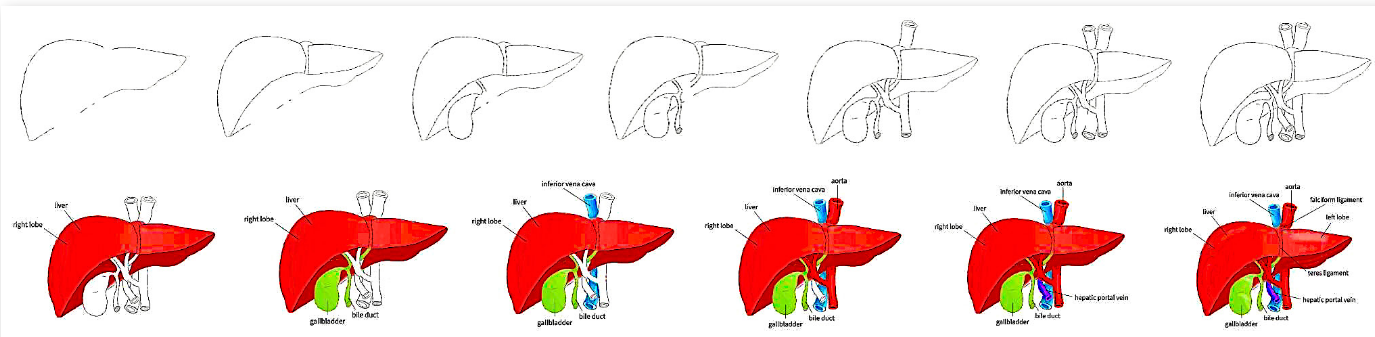

Figure 5. *Step-by-step drawings of the liver and gallbladder.*

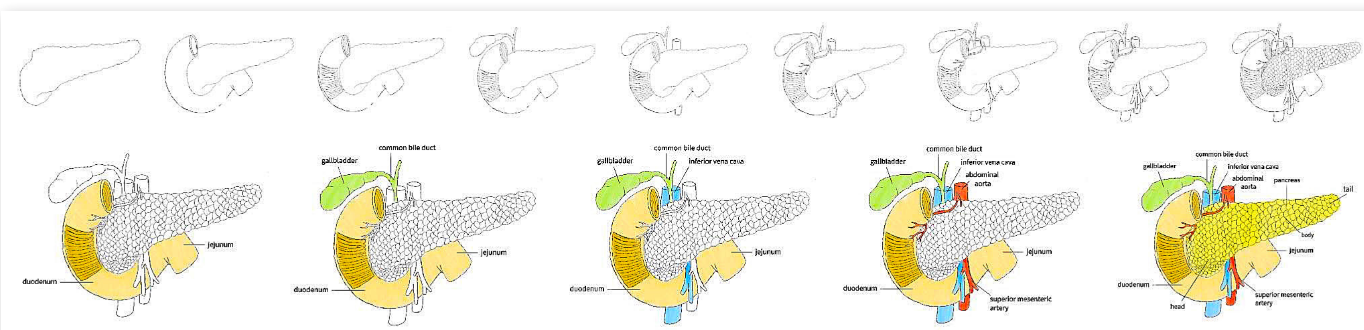

Figure 6. *Step-by-step drawings of the pancreas and surrounding organs.*

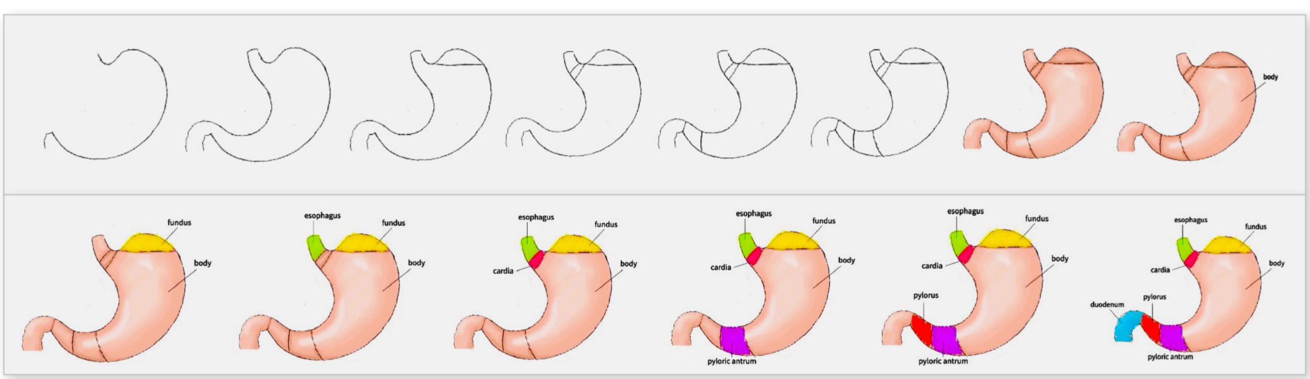

Figure 7. *Step-by-step drawings of the stomach.*

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Statistics Analysis

All statistical analyses were performed using IBM® SPSS® Statistics version 28, with the significance level set at 0.05. Descriptive statistics were calculated to summarize the study sample. Data distribution was evaluated through skewness and the Shapiro–Wilk test of normality, which indicated that student test scores were not normally distributed ($p < 0.05$). Consequently, non-parametric tests (Kruskal–Wallis H test and Mann–Whitney U test) were used for group comparisons. Within the drawing group, Pearson correlation analyses were conducted to explore relationships among students' perceived benefit of the drawing activity, their self-reported improvement in performance, and their final course grades. Qualitative data on student perceptions of guided drawing were independently coded and organized by two authors (V.W. and R.S.) to identify recurring patterns, concepts, and themes. Only themes on which both reviewers reached agreement are presented.

Results

Descriptive Statistics

To evaluate the impact of drawing-based pedagogy on student performance, descriptive statistics were calculated for the drawing ($n = 45$) and non-drawing ($n = 46$) groups across three course assessments: a digestive unit lecture quiz (10 questions worth 10 points), a digestive unit lab quiz (20 questions worth 20 points) , and their final course grade (0-100 point scale based on accumulative weekly lecture and lab quizzes plus midterm and final exams).

Students in the drawing group exhibited a slightly higher mean score on the lecture quiz ($M = 7.53$, $SD = 2.02$) than those in the non-drawing group ($M = 7.30$, $SD = 1.72$). Median scores (8.00 versus 7.50) also favored the drawing group. The range of scores was broader in the drawing group (0–10) compared to the non-drawing group (4–10), and variance was slightly higher (4.07 vs. 2.97), suggesting greater performance dispersion. The distribution in the drawing group was more negatively skewed (Skewness = -1.25) and leptokurtic (Kurtosis = 3.04), indicating a greater concentration of high-performing students.

The drawing group had a higher mean lab quiz score ($M = 15.93$, $SD = 3.76$) than the non-drawing group ($M = 15.72$, $SD = 3.31$). Both groups had the same median score (17.00). The drawing group showed greater variability in scores (range = 0–20) than the non-drawing group (range = 8–20). The drawing group's distribution was markedly skewed (Skewness = -2.08) and highly kurtotic (Kurtosis = 6.40), again suggesting a large cluster of high scores with few outliers.

Final grades were nearly identical between the two groups. The drawing group averaged 83.75% (SD = 9.33%) while the non-drawing group averaged 83.87% (SD = 9.38%). Median grades were similar (84.28% for the drawing group versus 85.47% for the non-drawing group). The range of grades for the drawing group was wider (56.34%–98.55%) than for the non-drawing group (62.36%–97.08%). Both groups showed mild negative skewness (≈ -0.61) and near-normal kurtosis, indicating relatively symmetric grade distributions centered on high performance. To further illustrate group performance differences, Figure 8 presents boxplots comparing the drawing and non-drawing groups across the lecture quiz, lab quiz, and final course grade.

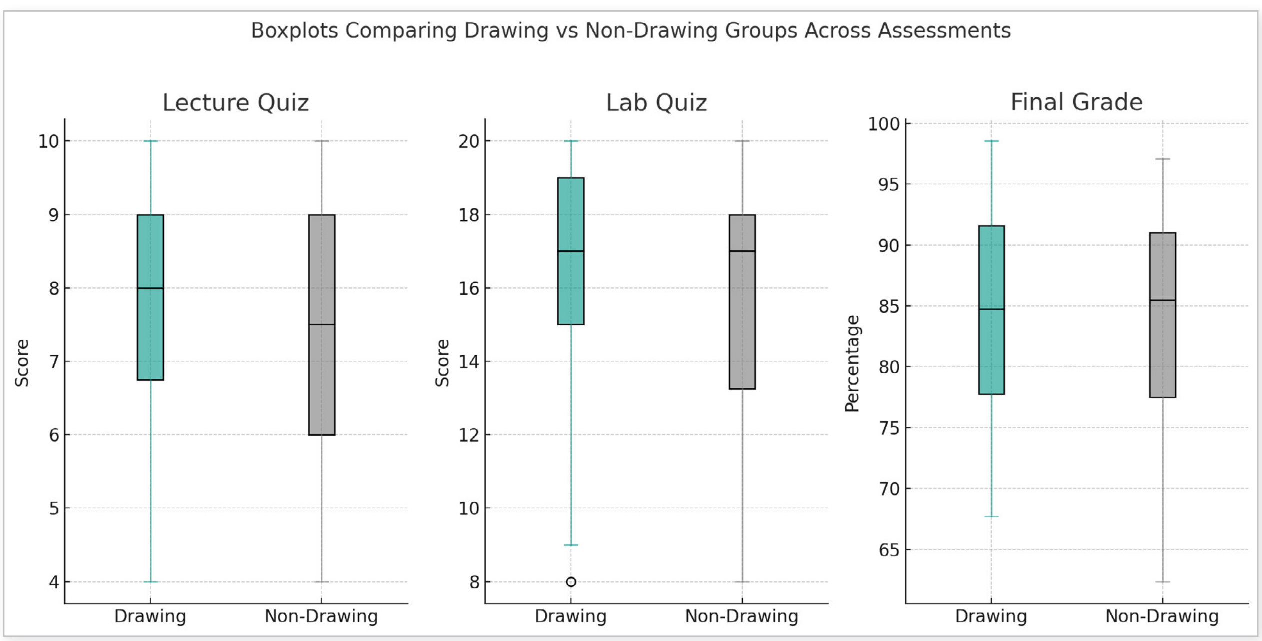

Figure 8. *Comparison of Drawing versus Non-Drawing groups' scores across lecture quiz, lab quiz, and final course grade*

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Inferential Statistics

To determine whether the observed differences in assessment performance between the two groups were statistically significant, non-parametric tests were used due to violations of normality assumptions.

A Kruskal-Wallis H test was used to evaluate differences in student performance between the drawing and non-drawing groups across three key assessments: the lecture quiz, lab quiz, and final course grade (Table 1). The analysis yielded no statistically significant differences between groups: Lecture Quiz, H(1) = 0.205, $p = 0.651$; Lab Quiz, H(1) = 0.016, $p = 0.898$; Final Course Grade, H(1) = 0.000, $p = 0.994$. While slight variations in mean ranks were noted, these did not achieve statistical significance, indicating comparable performance distributions across the two instructional approaches.

To further explore group-level differences, Mann-Whitney U tests were conducted for each assessment. Consistent with the Kruskal-Wallis findings, no statistically significant differences emerged: Lecture Quiz, U = 1125.5, Z = -0.511, $p = 0.609$; Lab Quiz, U = 1112.0, Z = -0.588, $p = 0.557$; Final Course Grade, U = 1080.5, Z = -0.774, $p = 0.439$. These results suggest that the integration of drawing activities into instructional practice did not produce a measurable difference in student outcomes as assessed by these instruments.

Although descriptive statistics suggested slight performance advantages for the drawing group, particularly on formative assessments like quizzes, these differences did not translate into statistically significant outcomes in summative course performance or final grades. The lack of significant findings may be attributed to sample size, score variability, or the strength of the intervention. Further research may be warranted to explore long-term learning retention and student engagement associated with drawing-based learning strategies.

The Pearson correlation test was used to explore the relationships between students' perceived benefits of the drawing activity, their self-reported improved performance, and their final course grades within the drawing group (Table 2). The findings revealed a strong, statistically significant positive correlation between perceived benefit and improved performance (r = 0.811, $p < 0.001$), suggesting that students who felt the drawing activities were beneficial also perceived themselves as performing better academically. This strong relationship supports the notion that engagement in drawing-based learning can enhance students' metacognitive awareness of their own learning processes and outcomes.

	Kruskal-Wallis H	Significance
Lecture quiz	.695	.405
Lab quiz	.208	.649
Final grade	.004	.949

Table 1. *Kruskal Wallis Test*

		Perceived Benefit	Improved Performance	Final Grade
Perceived Benefit	Pearson Correlation	1	0.811	0.170
	Sig. (2-tailed)		<0.001	0.264
	N	45	45	45
Improved Performance	Pearson Correlation	0.811	1	0.058
	Sig. (2-tailed)	<0.001		0.705
	N	45	45	45
Final Grade	Pearson Correlation	0.170	0.058	1
	Sig. (2-tailed)	0.264	0.705	
	N	45	45	91

Table 2. *Pearson correlation between the perceived benefit, improved performance, and final grade in the drawing group.*

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However, neither perceived benefit (r = 0.170, $p = 0.264$) nor improved performance (r = 0.058, $p = 0.705$) showed a statistically significant correlation with final grades. These findings indicate that while students in the drawing group reported high subjective value and perceived gains from the activity, these perceptions did not directly translate into measurable differences in final exam performance within this specific sample. These results highlight the complex nature of learning outcomes, where subjective student engagement and perceived benefits may not always be captured through traditional summative assessment metrics. Nonetheless, the positive subjective response aligns with pedagogical goals of increasing motivation and learner-centered engagement, which are emphasized in educational best practices.

Qualitative Analysis

Analysis of open-ended feedback from students in the drawing group revealed rich insights into how this pedagogical intervention was received and perceived. Of the 33 students in the drawing group who provided qualitative responses, 29 (88%) explicitly indicated that drawing positively impacted their understanding of anatomy and physiology. A dominant theme in the qualitative responses was the value of visual learning. Nearly 82% of students used language that connected drawing with a deeper understanding or visualization of anatomical concepts. Terms such as "*visualize*," "*remember*," "*see how it all connects*," and "*draw it out to understand*" were frequently repeated. For instance, one student commented: *"Drawing allowed me to visualize and retain the pathways more clearly. It helped me a lot when studying for exams.* "Another reflected on the unique value of drawing in comparison to passive learning strategies: *"Seeing the structure and then drawing it helps solidify it. Reading it in a book isn't the same."* This aligns with the strong positive correlation identified between perceived benefit and improved performance in the statistical analysis, further reinforcing the educational impact of this active learning method.

In addition to comprehension, "*engagement*" was frequently mentioned as a benefit. Roughly 70% of respondents stated that drawing made the material more interesting or kept them more focused in class. One student explained: *"I don't usually like lectures, but when we drew, I paid more attention, and it made class go by faster."* Another noted: *"It was fun and helpful at the same time, especially when we got to color-code or label the diagrams. I was way more engaged than just listening."* These observations are particularly relevant given the growing emphasis on active learning strategies in higher education, and they support high-impact practices and student-centered learning.

Despite the overwhelming positive feedback, some students (15%) mentioned challenges, primarily around pacing or anxiety tied to artistic performance. One student described: *"Sometimes I felt rushed, and I didn't want my drawings to be sloppy, so I stressed a bit."* Another echoed a similar concern: *"I'm not good at drawing, so I worried mine wouldn't be as accurate or helpful. But I still learned from doing it."* These comments suggest that future iterations of the intervention could benefit from modifications such as extended time for drawing tasks, guided templates, or reassurances that artistic quality is not being graded.

Perhaps the strongest evidence for the intervention's success came from students who volunteered statements like: *"This was one of the best ways I've ever studied for anatomy. I hope you keep doing this with future classes."*, *"It helped me not only on the test, but I actually remember more now weeks later."* Taken together, this qualitative feedback reflects a compelling endorsement of drawing as a powerful educational tool. The fact that 88% of students identified it as beneficial supports the earlier inferential statistics and adds human-centered context to the measurable performance improvements. The integration of subjective and objective data provides a more holistic understanding of the impact and reinforces the potential of drawing as a high-impact pedagogical practice in anatomy and physiology education.

To visually represent the dominant themes identified in the qualitative analysis, Figure 9 presents a word cloud generated from student responses, while Figure 10 showcases selected student drawings from the drawing group.

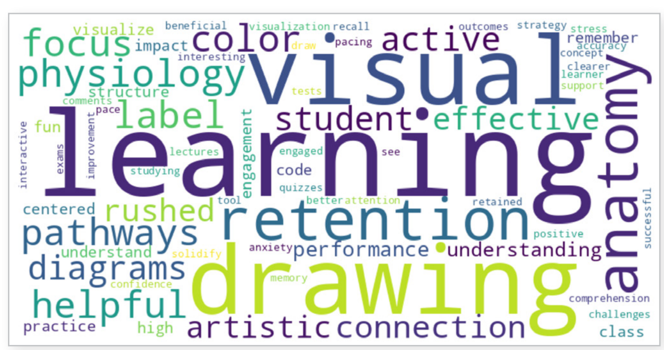

Figure 9. *Word cloud generated from student responses*

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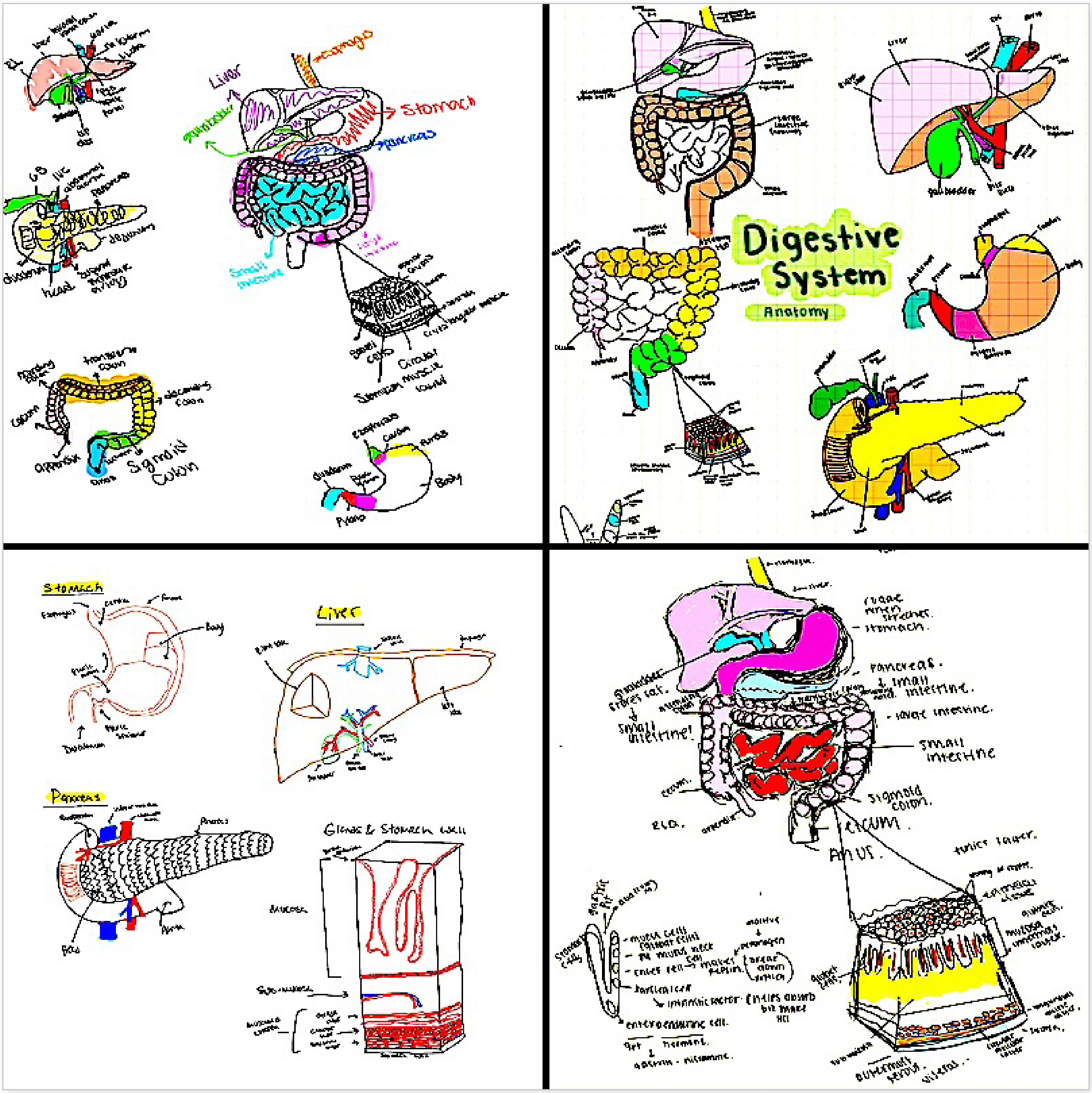

Figure 10. *Examples of student work from the drawing group*

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Discussion

This study investigated the impact of integrating guided drawing activities into undergraduate A&P instruction, comparing student performance and perceptions between a drawing-based intervention group and a traditional lecture-based control group. While quantitative analyses revealed no statistically significant differences in assessment scores between groups, qualitative findings highlighted clear perceived benefits of drawing as a learning strategy.

Consistent with prior research on the "drawing effect" (Quillin & Thomas, 2015; Wammes et al., 2016), descriptive statistics indicated slightly higher mean scores for the drawing group on both lecture and lab quizzes. Although these differences did not reach statistical significance, they align with the hypothesis that drawing facilitates deeper encoding through multisensory integration (Fernandes et al., 2018). The broader score distributions and more negatively skewed performance in the drawing group suggest that drawing may have particularly benefited high-performing students, potentially by enhancing their visualization and retention of complex anatomical structures.

Qualitative results further reinforced these interpretations. A substantial majority (88%) of students in the drawing group reported that drawing positively impacted their understanding, with common themes emphasizing visualization, improved memory, and enhanced comprehension of anatomical relationships. Students' repeated use of terms such as "visualize," "remember," and "see how it all connects" aligns with previous findings that drawing promotes active engagement, metacognition, and integration of new knowledge into existing cognitive frameworks (Quillin & Thomas, 2015; Wu & Rau, 2019).

Moreover, approximately 70% of students reported increased engagement when drawing, echoing studies that describe drawing as an enjoyable and interactive alternative to passive learning (Greene, 2018; Martínez et al., 2025). Engagement is a critical factor in student motivation and learning outcomes (Fiorella & Zhang, 2018), suggesting that drawing-based instruction may support learner-centered goals even if performance gains are not immediately evident in summative assessments.

Despite the overwhelmingly positive perceptions, some students reported challenges with drawing activities, including pacing concerns, artistic confidence, and difficulty multitasking between drawing and lecture explanations. These findings mirror Fiorella and Zhang's (2018) caution that drawing without adequate scaffolding or time allocation can overwhelm learners and potentially detract from content mastery. Ensuring clarity in instructional expectations, providing guided templates, and emphasizing the purpose of drawing as a learning tool rather than an artistic assessment may mitigate these challenges in future implementations.

Additionally, this study did not find significant differences in final course grades between groups, and perceived benefit was not correlated with summative performance outcomes. This suggests that, while drawing enhances immediate comprehension and perceived retention, its impact on long-term learning gains may depend on factors such as frequency of use, integration with other learning modalities, and alignment with assessment design (Wu & Rau, 2019).

Findings from this study support drawing as a valuable pedagogical strategy for enhancing student engagement and perceived understanding in anatomy education. Drawing can be effectively incorporated into lectures to promote active learning, support visualization of spatially complex structures, and increase student confidence in their anatomical knowledge. However, educators should consider pacing adjustments, provide reassurances about artistic expectations, and integrate drawing with complementary instructional methods to maximize its benefits for diverse learners.

Future research should explore the long-term impacts of drawing-based learning on retention beyond immediate quizzes, as well as its effects across diverse content areas within anatomy and physiology. Experimental designs incorporating pre- and post-testing, delayed retention assessments, and randomized assignment could strengthen causal inferences about drawing's efficacy. Additionally, examining how drawing influences higher-order thinking skills such as clinical reasoning, application, and integrative problem-solving would further clarify its role in health science education.

Limitations and Future Research

While the findings of this study support the use of medical drawing in A&P II courses, several limitations must be acknowledged. First, the study was limited to two sections of a single course at one institution, which constrains the generalizability of the results. Future research should account for potential confounding factors such as instructor variability, consistent integration of drawing activities across multiple course units, and students' prior knowledge, all of which may influence learning outcomes.

Second, medical drawing was implemented in only one weekly module. This limited exposure likely reduced its impact on overall course grades, which is reflected in the absence of significant differences between the drawing and non-drawing groups. Broader and more consistent use of guided drawing throughout the course may yield more robust effects on student performance.

Third was the absence of a pre-test measure to establish baseline equivalence between the two groups. Without an initial assessment, it is not possible to determine whether differences in prior knowledge, preparation, or ability existed between the sections at the outset of the course. This gap in design also limited the interpretation of post-test results,

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as any observed similarities or differences could not be confidently attributed to the intervention alone. For example, it remains unclear whether the drawing group may have begun at a disadvantage and the guided drawing activities helped narrow the gap, which would have been an important finding even in the absence of statistically significant differences. Future studies should incorporate pre- and post-test measures to better evaluate group comparability and the true impact of drawing-based instructional strategies.

Implications for Practice

The findings of this study suggest that guided drawing can be a valuable complement to traditional lecture methods in A&P II courses. Even without significant improvements in test scores, students' strong positive perceptions highlighted drawing as an effective tool for deepening comprehension and maintaining engagement. For instructors, this implies that incorporating structured drawing activities, whether integrated into lectures, used as formative practice, or applied in group settings can foster more active, multisensory learning environments. Such strategies may also benefit students with diverse learning preferences by encouraging visualization, reinforcing memory, and promoting meaningful connections between structure and function. As a low-cost and easily adaptable approach, guided drawing represents a practical enhancement to A&P instruction that aligns with evidence-based recommendations for active learning in the health sciences.

Conclusions

Overall, this study adds to the growing body of evidence positioning drawing as a powerful instructional tool in anatomy education. While measurable performance gains were not statistically significant in this sample, students overwhelmingly perceived drawing as beneficial for understanding and engagement. The integration of drawing-based activities with traditional lectures can transform passive learning into an interactive, multisensory experience, aligning with educational best practices that promote active, student-centered learning environments.

About the Authors

Valerie Weiss, MD, MS is an Assistant Professor in the Department of Rehabilitation Sciences at Florida Gulf Coast University, Fort Myers, Florida, teaching undergraduate A&P to students in the pre-health professions. As a trained medical illustrator, her research interest is in using drawing to enhance her students' anatomy education. Vanessa Kinley is an undergraduate student at Florida Gulf Coast University pursuing a Bachelor of Science in Biotechnology with minors in Chemistry and Biomedical Arts. She was introduced to medical illustration through a course at FGCU, which led to her interest in enhancing anatomical education by combining visual art with scientific study. She intends to continue her education and aspires to build a career in the medical device industry. Rob Sillevis is an Associate Professor who teaches research, movement sciences, and physical therapy courses in a Doctor of Physical Therapy program. He has had a long-standing interest in active learning strategies.

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Student Academic Performance and Motivation in an Alternatively Graded Undergraduate Pharmacology Course

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Abstract

This study investigated the impact of an ungrading scheme in an undergraduate pharmacology course, focusing on student performance, motivation, and course accessibility. Conducted in a 16-week, 400-level pharmacology course with 96 student participants, in this study we utilized pre-/post-knowledge checks, a self-determination index (SDI), and student surveys. The alternative grading scheme incorporated mastery-based quizzes, second-chance exams, and projects, designed to shift focus from traditional grades to continuous feedback and mastery. Results indicated a statistically significant increase in student content knowledge from pre- to post-course assessments. However, the results of this study also revealed a statistically significant decrease in student motivation (SDI) by the course's end. Furthermore, while ungrading aims to reduce grade-related stress, neither prior knowledge nor initial motivation predicted first exam success, and students with self-reported learning disabilities performed significantly worse on exams. These findings suggest that while ungrading has previously been shown to effectively enhance student satisfaction outcomes in STEM courses, its implementation requires careful attention to sustaining motivation and ensuring accessibility for all learners. This research highlights the need for nuanced ungrading design and continued investigation to fully realize its potential benefits in higher education. https://doi.org/10.21692/haps.2026.005

Key words: pharmacology education, ungrading, student motivation, inclusivity, specifications-based grading

Introduction

Undergraduate students often avoid challenging STEM courses, citing perceived difficulty, lack of confidence, and the abstract nature of these subjects (Kaleva et al., 2019). This fear of failure, coupled with the pressure to maintain high GPAs, acts as a significant deterrent, impacting students' willingness to enroll in demanding STEM courses (Sanstad, 2018). Although educational accessibility is frequently framed in terms of physical accommodations, research increasingly emphasized that barriers to access also arise from cognitive load, time constraints, assessment structures, and competing life responsibilities, disproportionately affecting neurodivergent learners and students in non-traditional roles (CAST, 2018; Dolmage, 2017). Addressing these barriers is critical for creating inclusive and engaging science learning environments.

One of the most detrimental aspects of traditional coursework contributing to these challenges is measurement-centric framing in undergraduate education, where systems heavily rely on quantifiable metrics (Freeman et al., 2014). This overemphasis on grades as the sole measure of academic ability can narrow students' focus on outcomes, reduce intrinsic motivation, diminish autonomy, and foster inequity (Brook, 2023; Chamberlin et al., 2023; Schlemer & Vanasupa, 2016; Whitcomb & Singh, 2021).
To counter these limitations, ungrading has emerged as a family of assessment approaches that reduce the centrality of traditional point-based grading systems. Within this family, specifications-based grading represents a structured implementation of ungrading principles. Specifications-based grading replaces numerical point accumulation with clearly articulated performance criteria ("specifications") tied to learning objectives, where student work is evaluation on a satisfactory/unsatisfactory basis and opportunities for revision are often emphasized. Final course grades, when required by institutional policy, are determined by the level and breadth of learning outcomes rather than by averaged, scores across assignments (Sorensen-Unruh, 2024).

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While ungrading and specifications-based grading vary in form, both prioritize formative feedback, mastery, and student agency over competitive ranking or point optimization. These features position specifications-based grading as a practical and scalable instantiation of ungrading that supports autonomy, intrinsic motivation, and sustained engagement with disciplinary learning (Guberman, 2021; McMillan & Hearn, 2008).

Ungrading is not a new concept but is rooted in decades of research on learning principles, drawing from foundational theories such as social constructivism, self-determination theory, and growth mindset theory (Bonner & Chen, 2009; Dweck, 1999; Ryan & Deci, 2000; Vygotsky et al., 1978; Yeager & Dweck, 2020). This theoretical grounding supports collaborative learning, fosters student autonomy in their educational paths, and encourages a resilient approach to academic challenges. Research in college-level STEM courses suggests that ungrading holds significant promise (Burns et al., 2024; Kalbarczyk et al., 2023). Studies indicate that ungrading can enhance intrinsic motivation, increase student engagement and effort, and deepen content understanding by reducing grade-related anxiety and promoting a focus on the learning process and revision (Burns et al., 2024; Butler, 2025; Kalbarczyk et al., 2023; Spurlock, 2023). Furthermore, some evidence points to improved student performance and confidence in understanding complex material within ungrading frameworks (Adler & Stoczynski, 2025; Bonilla & Findley, 2024; Stenson, 2022).

Implementing ungrading in challenging science courses, such as pharmacology where students must integrate several years of coursework and often enter with varying levels of background knowledge, presents a compelling solution for addressing knowledge gaps. Ungrading's emphasis on continuous feedback, peer collaboration, and opportunities for revision and improvement can create a more flexible and personalized learning environment. Traditionally gaining traction in social science classrooms—such as political science courses, psychology courses, and classes that utilize writing as a main form of assessment—its application in STEM courses is feasible despite the factual content and procedural knowledge involved (Kehlenbach, 2023; McNall & Gravelin, 2024; Sorensen-Unruh, 2024). Incorporating aspects of ungrading through alternatives to traditional exams, such as formative assessments, projects, or oral examinations, allows instructors to assess deeper learning and application within STEM constraints.

Despite the recent surge in institutions offering undergraduate pharmacology courses, this field notably lacks sufficient educational research and innovation (Hale et al., 2009; Kennedy, 2019; Rubaiy, 2021; Seeley et al., 2021). This gap highlights a timely opportunity to explore and evaluate alternative assessment strategies, such as ungrading, in a discipline that demands high levels of knowledge integration.

This study had two objectives: (1) evaluate students' performance and motivation across an ungrading upper-level pharmacology course, and, (2) evaluate how students with learning-related disabilities or lower prior knowledge are differentially influenced by the ungrading scheme.

Methods

Ethical Research Statement & Consent Protocol

This project was approved by the Institutional Review Board of Colorado State University (IRB Protocol #5596) prior to the commencement of the study, and informed consent was obtained from all participants. Participation in the study was voluntary, and participants did not receive compensation or any kind of benefit, such as extra credit. Student ID numbers were collected from the Pre-Course Assessment and Post-Course Assessment from Qualtrics to mark students' response as complete in the Gradebook. However, no research data was viewed or analyzed until final grades were submitted and finalized at the end of the Spring 2025 semester. All students enrolled in the course engaged in the interventions associated with the study including the Pre-Course Assessment and Post-Course Assessment. Students enrolled in the course were offered the opportunity to participate in the study via an opt-in consent process administered during the Pre-Course Assessment.

Context

This research was conducted within a 3-credit, 400-level undergraduate pharmacology course during the spring 2025 semester at a large, public research university. The course was delivered as a standard 16-week, in-person class delivered by one instructor and served as an upper-level elective. Required pre-requisite coursework to enroll in this pharmacology course included (1) a human physiology course and (2) either a cell biology or biochemistry course.

The student population (n = 100) was interdisciplinary, attracting majors from various programs across the university. Key fields of study represented by the students included biomedical sciences, biological sciences, psychology, biochemistry, neuroscience, data science, and toxicology. Of the 100 students enrolled, 96 consented to have their data included in this research, yielding a participation rate of 96%.

The course covered general principles of pharmacology (*i.e.*, pharmacodynamics, pharmacokinetics, rational dosing, adverse drug reactions, considerations for special populations) in Unit 1. Unit 2 covered antibiotics and neurological agents. Unit 3 covered autonomic nervous system & cardiovascular agents while Unit 4 covered diuretics, cancer chemotherapy, opioids, and cannabinoids.

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Pre-Course and Post-Course Assessments

Pre-Course and Post-Course Assessments were administered to students on the first day of class and during final exam week, respectively. Both assessments were created as surveys in Qualtrics (Qualtrics, Provo, UT) and each had four sections: (1) Knowledge Check, (2) Academic Motivation Scale – College Version, (3) Accessibility Questionnaire, and (4) Assessments Questionnaire. Additionally, the Pre-Course Assessment collected demographic information.

The Knowledge Check consisted of five instructor-developed multiple-choice questions designed to sample conceptual understanding from each of the major instructional units of the course. Specifically, questions assessed concepts related to general pharmacology principles and a selection of drug agents. Because the assessment was embedded within broader pre- and post-course surveys, the Knowledge Check was intentionally brief to minimize survey fatigue while still capturing overall changes in pharmacological understanding. To our knowledge, no widely adopted society-level learning outcomes framework currently exists for undergraduate pharmacology comparable to those available in disciplines such as anatomy and physiology or genetics; therefore, questions were aligned with the instructor's course learning objectives. The items were instructor-developed and have not been previously validated or published.

The Academic Motivation Scale – College Version (AMS-C 28; Vallerand, 1992) is a validated 28-item instrument and was used to calculate a self-determination index as described previously (Zeng & Yao, 2023). The Accessibility Questionnaire was a survey used to understand significant barriers to success and which accommodations or course modifications are most helpful for each student. The Assessment Questionnaire included questions on the students' familiarity with ungrading (Pre-Course Assessment) as well as benefit of ungrading and desire to see more courses with ungrading (Post-Course Assessment).

Mastery-Based Quizzes

Each weekly module typically included approximately 6–10 learning objectives, and quizzes consisted of 10 questions designed to sample across these objectives. Item banks were constructed with multiple question variants for each objective, typically containing 5–10 questions per objective. During each quiz attempt, the Canvas system randomly selected questions from these banks, ensuring that students encountered different question variants across attempts while still being assessed on the same conceptual learning objectives. This design allowed repeated attempts to reinforce learning and provide additional practice without relying on simple memorization of previously seen questions.

ChatGPT (ChatGPT-4o) was used to assist in generating initial drafts of quiz questions and explanations using structured prompts requesting undergraduate-level pharmacology questions targeting specific learning objectives (e.g., "Generate multiple-choice questions assessing the mechanism of action and clinical effects of beta-adrenergic antagonists appropriate for an upper-division undergraduate pharmacology course"). All generated questions were reviewed and edited by the instructor prior to inclusion in the quiz banks. Each quiz question included feedback explaining the correct answer as well as brief explanations of why the incorrect options were not correct. These "feedback-rich" explanations were designed to support formative learning by reinforcing key pharmacological concepts and helping students identify misconceptions following each attempt. Students had unlimited attempts, and the highest scoring attempt was used in the gradebook.

Second-Chance Exams

Although ungrading seeks to shift attention away from high-stakes examinations, institutional and departmental expectations required the inclusion of summative exams in this course. Within this implementation, exams functioned as mastery checkpoints rather than traditional grade-determining assessments. Students were required to demonstrate a minimum level of competence (≥70%) on each exam and were provided opportunities for revision through a second-chance testing system. Consequently, exam performance served as a standardized indicator of conceptual mastery while remaining aligned with the broader philosophy of ungrading.

The course included three unit exams (Unit 2, Unit 3, and Unit 4), that were adapted from instructor-developed exams used in previous offerings of the course and aligned with the learning objectives for each instructional unit. Students were required to achieve a score of 70% or higher on each exam to demonstrate mastery of the unit content.

If students did not meet the passing threshold on the first attempt, a second-chance testing scheme was used. Students received an individualized email report identifying the pharmacological concepts associated with missed questions along with a summary of drugs and topics that required further review. ChatGPT (ChatGPT-4o) was used to assist in generating these feedback summaries, which were reviewed by the instructor prior to distribution to students. Students then returned to the classroom to complete a second exam consisting of new questions assessing the same concepts they previously missed. Rather than retaking the entire exam, students completed new questions corresponding only to the concepts they missed on the initial attempt. Each correctly answered "repair" question restored the corresponding points to the student's original exam score.

All students were also required to complete an exam wrapper after each exam, regardless of their score, to encourage reflection on study strategies and performance. Exam wrappers were used primarily to encourage metacognition and were used when students reached out to meet for content/study support.

Exams were administered on Fridays during the scheduled class period. Students who did not meet the passing

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threshold were invited to complete a second-chance exam the following Monday during the regularly scheduled class time. During these sessions, students who did not require a retake were assigned asynchronous learning activities designed to review or introduce physiological concepts relevant to the upcoming pharmacology unit. Students completing the retake were also responsible for reviewing this asynchronous material prior to the next class meeting. These activities were intentionally aligned with the physiological systems that would be addressed in the subsequent pharmacology unit. This structure allowed second-chance exams to be administered efficiently without disrupting the overall course schedule while ensuring that all students remained engaged in course-relevant learning activities.

In-Class Activities

In-Class Activities (ICAs) were designed to promote active learning and application of pharmacological concepts through collaborative problem solving and case-based discussion. A total of seven ICAs were implemented throughout the semester, each aligned with a specific class of pharmacological agents covered in the course. During these activities, students worked in small groups to analyze drug mechanisms, predict physiological effects, interpret clinical scenarios, and discuss therapeutic decision-making. Activities frequently required students to apply concepts such as receptor pharmacology, pharmacokinetics, drug interactions, and adverse effects to realistic or simplified clinical contexts.

Participation was recorded using iClicker to verify attendance and engagement, and students received a "Complete" designation for participating in the activity. ICAs were designed as formative learning opportunities rather than graded assessments, providing students with opportunities to practice applying pharmacological principles in a low-stakes environment while receiving immediate feedback through peer discussion and instructor facilitation.

Projects

Projects were used to assess student understanding through applied and integrative assignments rather than traditional examinations. In the Unit 1 Project, students created a concise pharmacology "drug information sheet" for a drug of their choosing. The assignment required students to synthesize key pharmacological concepts including drug class and indications, mechanism of action, pharmacokinetics and dosing (ADME), adverse effects and toxicities, and clinical considerations for special situations such as pregnancy, organ dysfunction, or drug interactions. Students were required to explain concepts in their own words and present the information in a clear and visually organized format.

The Final Project consisted of a written clinical pharmacology case study developed by the instructor. Students were randomly assigned one of five patient scenarios involving commonly used pharmacologic agents (e.g., propranolol, pseudoephedrine, ibuprofen, albuterol, or lisinopril). For each case, students summarized the clinical presentation, described the mechanism of action of the relevant drug, explained the physiological effects of the drug class, connected the patient's symptoms to the pharmacology, and proposed appropriate therapeutic interventions. The assignment was designed to assess students' ability to apply pharmacological principles to realistic clinical contexts.

Grading Scheme

A specifications-based grading scheme was used to determine final course letter grades as shown in Table 1.

	Requirement for A (Advanced Mastery)	Requirement for B (Proficient Mastery)	Requirement for C (Adequate Mastery)	Requirement for F (Insufficient Evidence of Mastery)
Pre-Course & Post-Course Assessment	Completed Pre-Course and Post-Course Assessments			Did not complete both Pre-Course & Post-Course Assessments
Syllabus Quiz	Completed Syllabus Quiz			Did not complete syllabus quiz
Mastery-Based Exams (3 total)	Passed all 3 exams with ≥ 70% (with exam repairs)			Did not pass all 3 exams with ≥ 70%
Exam Wrappers	Completed all 3 exam wrappers			Did not complete all 3 exam wrappers
Unit 1 Project	All rubric criteria were met			Some or no rubric criteria were met
Final Project	All rubric criteria were met			Some or no rubric criteria were met
Mastery-Based Quizzes (8 total)	Passed all quizzes with ≥ 90%	Passed all quizzes with ≥ 80%	Passed all quizzes with ≥ 70%	Did not pass all quizzes with ≥ 70%
In-Class Activities (7 total)	Completed all In-Class Activities			Did not complete all In-Class Activities

Table 1. *Detailed course grading scheme from syllabus (excerpt).*

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Data Analysis

The Pre-/Post-Knowledge Checks were scored for accuracy out of a total of 5 points. A self-determination index (SDI) was calculated using the AMS-C 28 as previously described (Zeng & Yao, 2023). Briefly, each item (of 28 items) corresponded to a type of motivation, and averages were calculated for each type of motivation. The SDI was calculated using the following formula:

$$2\,x\left(\frac{know + acc + stim}{3}\right) + iden - \left(\frac{intro + reg}{2} + 2\,x\,amo\right)$$

Abbreviations from formula:

- know = intrinsic motivation to know
- acc = intrinsic motivation to accomplishments
- stim = intrinsic motivation to experience stimulation
- iden = identification
- intro = introjected regulation
- reg = external regulation
- amo = amotivation

Responses to the Accessibility Questionnaire and Assessments Questionnaire (including familiarity with ungrading, benefit of ungrading, and desire for more ungrading) were analyzed using descriptive statistics (means, standard error of means).

Exam averages were calculated using students' first attempt on each exam (Unit 2 Exam, Unit 3 Exam, & Unit 4 Exam) only.

Statistics

All statistical analyses were conducted using GraphPad Prism (Version 10.4.2; GraphPad Software, San Diego, California, USA). The pre-determined significance level for all tests was set at $\alpha = 0.05$.

To compare changes in student scores from the beginning to the end of the course, Wilcoxon matched-pairs signed rank tests were performed. Specifically, these tests were used to analyze differences between Pre- versus Post-Knowledge Check scores and Pre- versus Post-Self-Determination Index (SDI) scores, as the data were not assumed to be normally distributed and involved paired observations.

To compare the performance between two independent groups of students, a Mann-Whitney U test was utilized. This test determined if there was a statistically significant difference in average exam performance between students who self-reported a learning disability and those who did not.

To assess the strength and direction of monotonic relationships between variables, Spearman Rank correlations (non-parametric) were conducted. Two specific relationships were investigated: (1) the correlation between students' reported enjoyment of the ungrading scheme (quantified from survey responses) and their average exam performance, and (2) the correlation between students' self-perceived benefit of the ungrading scheme (also from survey responses) and their average exam performance.

Simple linear regressions were employed to assess predictive relationships among continuous variables. A regression was conducted to determine if Pre-Knowledge Check scores predicted Unit 2 Exam performance. Separately, additional simple linear regressions explored the predictive ability of Unit 2 Exam performance on subsequent Unit 3 and Unit 4 Exam scores.

Finally, logistical regressions were utilized to determine if initial student characteristics predicted the binary outcome of passing or failing a specific exam on the first attempt. Specifically, these analyses assessed whether Pre-SDI scores or Pre-Knowledge Check scores predicted the likelihood of a student passing (> 70%) or failing (< 70%) the Unit 2 Exam on their first attempt.

Results

Descriptive statistics for student exam performance are presented in Table 2. Across the three unit exams and the overall exam average, mean scores (%) ranged from 79.8±1.5 (Unit 3 Exam) to 85.4±1.3 (Unit 4 Exam), with an overall course exam average of 82.0±1.0. The percentage of students requiring a second chance to pass an exam varied by unit, with the Unit 3 Exam having the highest retake rate (25.53%), and both Unit 2 and Unit 4 Exams having a lower, identical retake rates (13.83%). On average, 17.73% of students were required to utilize the second-chance retake option across all exams.

	Unit 2 Exam	Unit 3 Exam	Unit 4 Exam	Exam Average
Mean ± SEM (%)	80.8 ± 0.9	79.8 ± 1.5	85.4 ± 1.3	82.0 ± 1.0
% of 2nd Chance Takers	13.83%	25.53%	13.83%	17.73%

Table 2. *Mean scores ± standard error of mean (SEM) and % of students who were required to do an exam retake for all exams.*

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To determine whether there was a statistically significant difference between student's Pre-Knowledge Check score and Post-Knowledge Check score, a Wilcoxon signed-rank test was used. This test indicated that Knowledge Check scores were significantly higher after the course and that the data was statistically significant ($W = 2965$, $p < 0.001$, $r = 0.32$), as shown in Figure 1.

The next question the researchers aimed to answer was if there was a statistically significant difference between student's Pre-SDI score and Post-SDI Score. A Wilcoxon matched-pairs signed-rank test was utilized which demonstrated that there was a statistically significant difference in scores meaning that by the end of the course, student's motivation had decreased ($W = -678$, $p = 0.0498$), as shown in Figure 2.

A simple logistic regression was used to understand if Pre-Knowledge Check scores predicted if a student would passe (1) or fail (0) the first exam on their first attempt ($n = 94$). The model was not statistically significant ($G^2 = 1.21$, $p = 0.2815$). This model also demonstrated little variance in exam performance (*Tjur's* $R^2 = 0.012$, *Cox-Snell's* $R^2 = 0.013$). The model indicated that Pre-Knowledge Check scores do not predict whether a student would pass or fail the first exam on their first attempt (Odds Ratio = 1.40, 95% CI [0.77, 2.68]), $B = 0.34$, $SE = 0.31$, $Z = 1.08$). The 95% confidence interval for the Odds Ratio included one which further supports that there is no statistically significant relationship between Pre-Knowledge Check scores and students passing or failing their first exam on the first attempt.

To determine whether Pre-SDI scores predicted if a student would pass (1) or fail (0) the first exam on their first attempt, a simple logistic regression was utilized ($n = 94$). This test demonstrated no statistical significance, indicating that Pre-SDI scores did not predict students passing or failing the first exam on their first attempt ($G^2 = 0.003$, $p = 0.9532$). Additionally, there was negligible variance in exam performance (*Tjur's* $R^2 < 0.001$, *Cox-Snell's* $R^2 < 0.001$). Pre-SDI scores did not predict students passing or failing the first exam on the first attempt (Odds Ratio = 0.99, 95% CI [0.74, 1.28]), $B = -0.008$, $SE = 0.14$, $Z = 0.06$). Furthermore, since the 95% confidence interval for the Odds Ratio contained one, this supports that Pre-SDI scores do not influence whether students pass or fail their first exam on the first attempt.

Post-course assessment data indicated high student satisfaction with the grading system. On a 5-point Likert scale, students strongly agreed that the grading was both beneficial to their success ($M = 4.61$) and personally enjoyable ($M = 4.64$). Figure 3 provides a complete visualization of these responses.

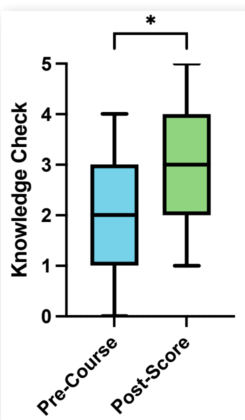

Figure 1. *Pre- versus post-course Knowledge Check scores. Comparison of student scores on a 5-point knowledge check administered at the beginning (pre-course) and end (post-course) of an undergraduate pharmacology course (n = 96). Data are presented as mean ± SEM.*

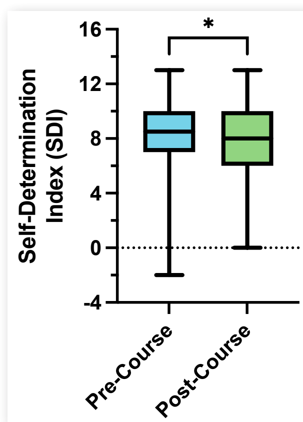

Figure 2. *Pre- versus post-course Motivation (SDI) scores. Student Self-Determination Index (SDI) scores measured at the beginning (pre-course) and end (post-course) of an undergraduate pharmacology course (n = 96). Data are presented as mean ± SEM.*

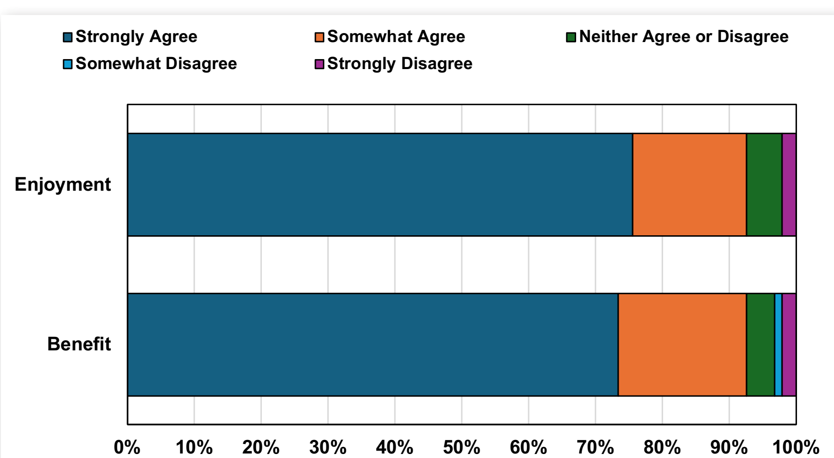

Figure 3. *Distribution of student (N = 94) responses to two Likert-scale items on the Post-Course Assessment concerning the grading system. The items were: "The grading in this course was beneficial to my success" (Benefit) and "The grading in this course was enjoyable for me as a learner" (Enjoyment).*

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A simple linear regression was conducted to determine if students who have a high self-perceived benefit from the ungrading scheme perform well on examinations ($n = 94$). The simple linear regression model was not statistically significant, $F(1,92) = 0.1967$, $p = 0.6585$, and accounted for 0.2% of the variance in exam average ($R^2 = 0.002$). Likert ratings for self-perceived benefit of ungrading did not significantly predict exam average ($B = 0.54$, $SE = 1.22$, 95% CI [-1.89, 2.97]). Since the 95% confidence interval for the unstandardized regression coefficient (B) included zero, this further indicated that there was no significant association between self-perceived benefit of ungrading and exam averages. A Spearman's rank-order correlation test was also used to assess the monotonic relationship between self-perceived benefit of ungrading Likert ratings and exam average. This relationship was not statistically significant ($r_s(92) = -0.03$, 0.7971). Furthermore, the 95% confidence interval for the Spearman's correlation coefficient (r_s) included zero [-0.23, 0.18] which supports the lack of any significant association and indicates that there is no significant monotonic relationship between self-perceived benefit of ungrading Likert ratings and exam average.

To analyze whether students who enjoyed the ungrading scheme performed well on examinations, a simple linear regression and a Spearman's rank-order correlation test were performed ($n = 94$). The simple linear regression found that there was no statistically significant correlation, $F(1,92) = 0.9452$, $p = 0.3335$, between enjoyment of ungrading and exam performance ($B = 1.23$, $SE = 1.27$, 95% CI [-1.29, 3.75]). The simple linear regression model accounted for 1.0% of the variance in exam performance ($R^2 = 0.010$). Since the 95% confidence interval for the unstandardized regression coefficient included zero, this also demonstrated that there is no significant correlation between students enjoying the ungrading scheme and performing better on exams. When examining the results from the Spearman's rank-order correlation test, there was no statistically significant relationship between student enjoyment of the ungrading scheme and examination performance, $r_s(92) = 0.06$, $p = 0.5882$. The 95% confidence interval for the Spearman's correlation coefficient included zero [-0.15, 0.26] which further supports this lack of a statistically significant relationship.

The final question that the researchers aimed to answer was whether students with learning-related disabilities performed well on exams within the context of the ungrading scheme. To answer this question, a Mann-Whitney U Test was used which found that students with learning-related disabilities (median = 75.00, $n = 6$) had lower exam average scores compared to students without learning-related disabilities (median = 84.00, $n = 88$). A Mann-Whitney U test indicated a significant difference in exam performance between students who reported having a learning-related disability (Yes) and those who reported not having a learning-related disability (No) ($U = 131$, $p = 0.0376$), with a large effect size (rank biserial correlation $r_{rb} = 0.50$), as shown in Figure 4. This data indicates that students with a self-reported learning disability performed worse on exams than students without a self-reported learning disability even with the ungrading scheme.

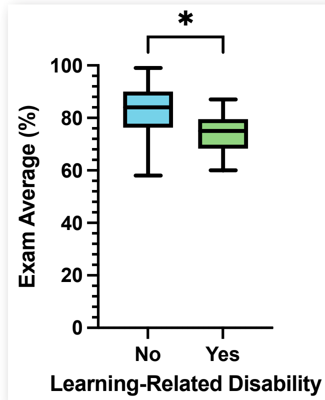

Figure 4. *Exam average scores for students with and without learning disabilities. Median exam average scores for students who self-reported having a learning-related disability (Yes, n = 6) compared to those who did not (No, n = 88) within the ungrading scheme. Data are presented as medians with interquartile ranges.*

Discussion

The present study examined the implementation of an alternative grading framework in an upper-division undergraduate pharmacology course and its potential effects on student learning and motivation. Overall, students demonstrated gains in pharmacological knowledge over the duration of the course, as evidenced by improvements in pre- and post-course Knowledge Check scores. These findings suggest that the course structure supported student learning of core pharmacological concepts. Although there was some overlap between pre- and post-course Knowledge Check scores, the effect size associated with this change (r = 0.32) suggests a moderate shift in performance. This indicates that while not all students improved equally, the overall distribution of scores moved meaningfully upward over the duration of the course.

It is important to note that the study design did not allow direct comparison between this alternative grading approach and a traditionally graded course. While the results demonstrated that students improved their knowledge over the course of the semester, the study did not provide evidence that alternative grading is more effective than conventional grading structures in promoting learning outcomes. Instead, these results demonstrated that meaningful learning gains can occur within an ungrading framework.

One potential explanation for the observed knowledge gains was the emphasis on iterative engagement with course material. Mastery-based quizzes provided multiple opportunities for students to revisit core concepts and receive feedback, allowing them to correct misunderstandings and reinforce their learning. Previous

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work in mastery learning and specifications-based grading has suggested that repeated opportunities for revision and feedback can promote deeper understanding and reduce the negative effects of high-stakes assessment environments (Bloom, 1968; Guskey, 2010; Nilson, 2015). The course design used in this study intentionally incorporated these principles by allowing multiple quiz attempts and second-chance exams focused on previously missed concepts.

These findings also have potential implications for courses within anatomy and physiology education, which share many instructional challenges with pharmacology. Both disciplines require students to integrate large volumes of mechanistic content while applying that knowledge to physiological systems and clinical contexts. Assessment structures in these courses are often heavily exam-centered, which can increase student anxiety and promote short-term memorization strategies rather than conceptual integration. The mastery-oriented assessment structure used in this study (combining iterative quizzes, opportunities for exam repair, and applied projects) may represent a promising approach for supporting learning in other content-dense life science courses, including anatomy and physiology. By shifting the emphasis from one-time high-stakes exams to repeated engagement with core concepts, such approaches may encourage deeper learning and improved retention of foundational physiological principles.

The course structure may also have influenced student motivation and learning behaviors. Prior research has suggested that traditional grading systems can increase performance anxiety and shift student focus toward grade optimization rather than conceptual understanding (Brook, 2023; Chamberlin et al., 2023; Freeman et al., 2014). In contrast, alternative grading approaches often aim to emphasize learning processes and student autonomy. In the present study, mastery-based quizzes and opportunities for exam revision may have encouraged students to view assessments as opportunities for learning rather than as one-time evaluative events.

Although SDI scores decreased slightly over the course of the semester and the difference reached statistical significance, the magnitude of this change was small and the distributions showed substantial overlap. As a result, this finding should be interpreted cautiously, as the practical significance of this difference in student motivation may be limited.

One survey item asked students whether "The grading in this course was beneficial to my success." This statement may be interpreted in multiple ways. Students may have interpreted this item as indicating that the grading structure helped them achieve a satisfactory course grade, while others may have interpreted it as meaning that the grading approach supported their learning and understanding of pharmacological concepts. Because the survey instrument did not explicitly distinguish between these interpretations, the results should be interpreted cautiously. Future work could clarify this distinction by including separate survey items examining perceived effects of grading systems on learning outcomes and course performance.

At the same time, the mechanisms underlying the observed learning gains remain uncertain. It is possible that reduced performance pressure associated with the ungrading framework contributed to improved engagement with course material. Alternatively, the increased time-on-task created by repeated quiz attempts and exam repair opportunities may have played a larger role in supporting student learning. The present study cannot distinguish between these possibilities, and it is likely that both factors contributed to the outcomes observed.

The study also explored outcomes for students with self-reported learning-related disabilities. Although the sample size for this subgroup was small, the analysis suggested that these students had lower exam average scores compared to their peers. Because only a small number of students reported a disability, these findings should be interpreted cautiously and warrant further investigation in larger and more diverse student populations.

Despite these complexities, several aspects of the course design appeared to support student learning. Students demonstrated measurable gains in pharmacological knowledge over the duration of the course, and exam averages remained strong despite the reduced emphasis on traditional point-based grading. The course structure provided multiple opportunities for students to engage with challenging material through iterative quizzes, exam repair opportunities, and applied projects. These elements allowed students to revisit difficult concepts and receive feedback throughout the semester rather than relying solely on high-stakes assessments. Together, these findings suggest that alternative grading structures can be implemented in rigorous, content-heavy STEM courses while still supporting measurable learning outcomes.

Several limitations of the present study should be considered when interpreting these findings. First, the study was conducted within a single course at a single institution, which may limit the generalizability of the results to other instructional contexts. Second, the absence of a control group using traditional grading prevented direct comparison between grading systems. Third, some analyses exploring potential differences among student subgroups were limited by small sample sizes, restricting the ability to draw strong conclusions about how ungrading may affect students from different backgrounds.

Despite these limitations, the results contribute to a growing body of literature exploring alternative grading practices in STEM education. The findings demonstrate that an ungrading framework can be implemented in a content-heavy course such as pharmacology while still supporting measurable learning gains. Importantly, the course design balanced

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the philosophical goals of ungrading with institutional expectations for academic rigor by incorporating competency-based exam thresholds alongside mastery-oriented formative assessments. Future research should examine the implementation of similar grading approaches across multiple courses and institutions and should directly compare learning outcomes between ungraded and traditionally graded course structures. Additional work examining how these grading approaches influence student study behaviors, motivation, and perceptions of learning would also provide valuable insight into the mechanisms through which alternative grading practices influence educational outcomes.

Conclusion

This study confirms that an ungrading scheme can effectively enhance student content knowledge in a demanding STEM course like pharmacology. While ungrading aims to alleviate some of the inherent pressures of traditional grading, such as grade-related stress and anxiety, our findings suggest this does not automatically translate into improved motivation or universally positive academic outcomes for all students, particularly those with self-reported learning disabilities. Ultimately, these results underscore the promise of ungrading in fostering deeper learning but also highlight the critical need for nuanced design and continued research to truly maximize its benefits across diverse student populations. Because many anatomy and physiology courses share challenges related to content density that are similar to those for pharmacology, the findings from this study may provide useful insights for educators exploring alternative grading models in those instructional contexts.

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EDUCATIONAL RESEARCH

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Career Exploration Activity for Undergraduate Human Anatomy & Physiology Students

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Abstract

Students enroll in Anatomy & Physiology (A&P) courses in pursuit of healthcare careers such as nursing and various allied health professions. To encourage students to be intentional in their academic and career planning and to improve student motivation in the course, we have designed a career exploration activity based on student self-reflection. This optional extra-credit activity guided students to investigate their current career choice, evaluate their progress on the path toward that career, and define their next steps accordingly. Students also provided their feedback on the helpfulness of the activity. In this article, we have shared the framework and design process for this activity, as well as the results of our pilot study in fall 2024 and spring 2025. Over the two semesters, 328 out of 513 students (64%) completed the activity. The most common student career choices were nursing, respiratory therapy, and physician assistant. In both semesters, over half of the students selected that they are currently "applying" for their professional program and described their next steps as exploring their career path options, gaining relevant experience, and applying to a program. Overall, 93% of students reported the activity as "helpful" or "very helpful." The two main reasons provided were that it promoted career planning and self-reflection. In addition, 56% of students requested to receive a follow-up survey three months later for accountability. In summary, we have developed and piloted a career reflection activity which can be used for pre-professional students to promote self-reflection and planning concrete action steps. https://doi.org/10.21692/haps.2026.006

Key words: career, college-to-career, self-reflection, nursing, planning

Introduction

Undergraduate human anatomy & physiology (A&P) courses are typically entry-level science courses originally designed as prerequisite coursework for students preparing for nursing school. The A&P curriculum is generally split into a 2-semester sequence of courses (A&P1 and A&P2) with the objective of building basic knowledge about the structure and function of the human body. This knowledge is a necessary foundation prior to taking nursing school coursework in disease mechanisms and treatment, such as pathology and pharmacology. Similarly, respiratory therapy (RT) programs also require completion of human A&P courses that students can build upon as they embark upon the undergraduate RT curriculum. Thus, for undergraduate programs in nursing and RT, the A&P course is incorporated in the undergraduate degree program. More recently, graduate-level Physician Assistant (PA) and Anesthesiologist Assistant (AA) programs have also required successful completion of A&P courses prior to applying for these programs. These A&P courses may be taken while a student completes an undergraduate degree, but often students who have previously completed an undergraduate degree program later return to college to complete these science prerequisite courses as part of their preparation to apply for the graduate program.

In our experience, almost all students who are taking A&P courses have their sights set on a career in healthcare, and progression into their chosen career requires successful completion of A&P. Even though this course is essential for career progression along pathways chosen by students, the course has a high DFW rate (Ediger, 2022). Experiencing the high DFW rate, year after year, while understanding the importance of the A&P course for student career progression led us to a consideration of student motivation factors.

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Students can be motivated by a variety of extrinsic and intrinsic factors. Based on the well-recognized self-determination theory (Deci & Ryan, 1985; 2012), intrinsic motivation is related to the inherent value, such as attractiveness, of the action itself, whereas extrinsic motivation pushes people to act because of the outcome, which is the driver for that type of motivation. There are multiple types of extrinsic motivation which have been described and arranged along a "motivation continuum." Identified motivation is a type of extrinsic motivation that is the closest to intrinsic motivation on the motivation continuum (Deci & Ryan, 2012).

Like intrinsic motivation, identified motivation is a form of autonomous motivation involving an individual's recognition and internal acceptance of the importance and value of a behavior, such as studying, that allows a person to reach the desired outcome (Burton et al., 2006; Liu et al., 2019). Although the benefit of identified motivation may be shorter in duration compared to that of intrinsic motivation, it can still be helpful and more effective than other forms of extrinsic motivation. Indeed, studies have suggested that students with identified motivation are more likely to function with an internal locus of control (Liu et al., 2019), have more autonomous motivational control and academic adjustment ability, are less likely to drop out, and have a higher sense of competency and intentionality (Deci & Ryan, 2012; Floris et al., 2024; Girelli et al., 2018; Nishimura & Joshi, 2021). Thus, promoting identified motivation in students is likely to support greater academic achievement. In addition, some studies suggest that having a career plan influences the relationship between academic self-efficacy and metacognitive skills which are directly correlated to academic motivation (Küçükaydin, 2024). Taken together, this suggests that helping students think about their future career and develop a career plan may also help them become more effective and more motivated to succeed in their A&P coursework. Increased academic success would then increase their chances of success in applying to programs such as nursing school.

College education can be viewed as a steppingstone to getting ready for a professional career in which students will be successful and personally fulfilled as integrated and productive members of our society. At the system-wide level, we are seeing an emphasis on "College-To-Career" programs for undergraduate students. In 2015, the National Association of Colleges and Employers (NACE) began its Career Readiness Initiative which defined career readiness as "a foundation from which to demonstrate requisite core competencies that broadly prepare the college educated for success in the workplace and lifelong career management" (NACE, 2025). The NACE task force proceeded to describe eight NACE career readiness competencies, including "career and self-development," which provide a scaffold for instructors to identify ways in which a particular course or individual assignment may develop career readiness in students. Our institution has adopted the College-to-Career paradigm as part of its current Quality Enhancement Plan. As part of a pathway to the health professions, the A&P course exists within this College-to-Career paradigm; faculty may consider learning outcomes and objectives within the context of helping students progress in their career.

This study aimed to promote the development of one of the NACE career readiness competencies, "career and self-development", in our A&P students by assisting them in 1) exploring their career choice, 2) evaluating their current position with respect to their career progression, and 3) planning their career development pathway. To reach these goals we have developed, adjusted, and piloted a Career Exploration assignment. Through this self-reflection activity, we hoped to increase student self-awareness and motivation for the course, especially identified motivation. We also hoped to encourage students to be intentional in their own education and career preparedness pathway. The results of this study will also help us better know who our A&P students are, so that we can adjust the course and future coursework for improved student success. An additional question of interest to us as faculty concerned identifying alterative professions where knowledge and skills in anatomy and physiology would be helpful. In other words, "What else can you do with anatomy?"

Methods

About the Course

At our institution, A&P2 is offered as a combined lecture and lab course, with 3 credit hours of lecture and 1 credit hour of lab. Lectures are taught by faculty and can include up to 120 students. Lab sections are capped at 24 students per section and taught by a graduate teaching assistant. In both fall 2024 and spring 2025, our institution offered 3 lecture sections; each lecture section was taught by one of the authors. Each lecture section included 72 to 120 students.

We are at a large R1 institution located in the southeastern United States. Our institution is a majority Minority Serving Institution with a high percentage of first-generation college students. The students in this study were all enrolled in the second semester of a two-semester human A&P course originally designed as a sophomore-level pre-nursing foundational science course. In the fall 2024 semester, 205 students were enrolled in the course, and 308 students were enrolled in spring 2025. Student populations were similar in fall 2024 and spring 2025 (Table 1), with female students representing 84% of the students. The average student age was 22.4 years of age. The racial classification of students was as follows: 53% black or African-American; 21% Asian; 18% white; 4% more than one race; 1% American Indian or Alaska Native; and 1% Hawaiian or other Pacific Islander (3% did not report racial identity). In addition, 17% of students reported Hispanic ethnicity, 63% checked that they were

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Pell-eligible, a marker of socioeconomic level, and 45% of students reported being first-generation college students. Students in their third year (juniors) represented 40% of students enrolled during these two semesters. Fourth-year students were 29% and second-year students were 27%. An additional 4% of students were classified as non-degree undergraduate.

Characteristic	Students Represented
Female	84%
Black or African-American	53%
Asian	21%
White	18%
More than 1 race	4%
American Indian or Alaska Native	1%
Hawaiian or other Pacific Islander	1%
Hispanic	17%
Pell-eligible	63%
First-generation	45%
Sophomore level	27%
Junior level	40%
Senior level	29%

Table 1. *Demographics of A&P Students*

Framework for Activity

The foundational expectation that grounded our activity design was an expectation that all A&P students can benefit from Career Exploration (Figure 1). Extensive experience instructing the A&P course sequence led to the understanding that there are students who are successful in the course and are confident in their career choice. These students can benefit from career exploration because they will learn more about how to be a competitive applicant to achieve admission into their desired professional program, and then how to continue to progress along that path and be successful in their career. Some of these confident students will not be admitted into their program of choice on the first attempt. For these students, knowledge of options can also be eye-opening. The second group of students represents students who are successful in the course but are less confident of their career path. This student may have an interest in health care, in general, but lack specific direction or detailed knowledge of possible career fields. This student can benefit from the opportunity for guided investigation of potential career opportunities and exploration activities such as internships and shadowing. The third group represents students who are not successful in the course. For these students, career exploration is a chance to evaluate why they are in the A&P course, whether this is where their interest truly lies, what they need to do to be successful in this career path, and what options exist for them.

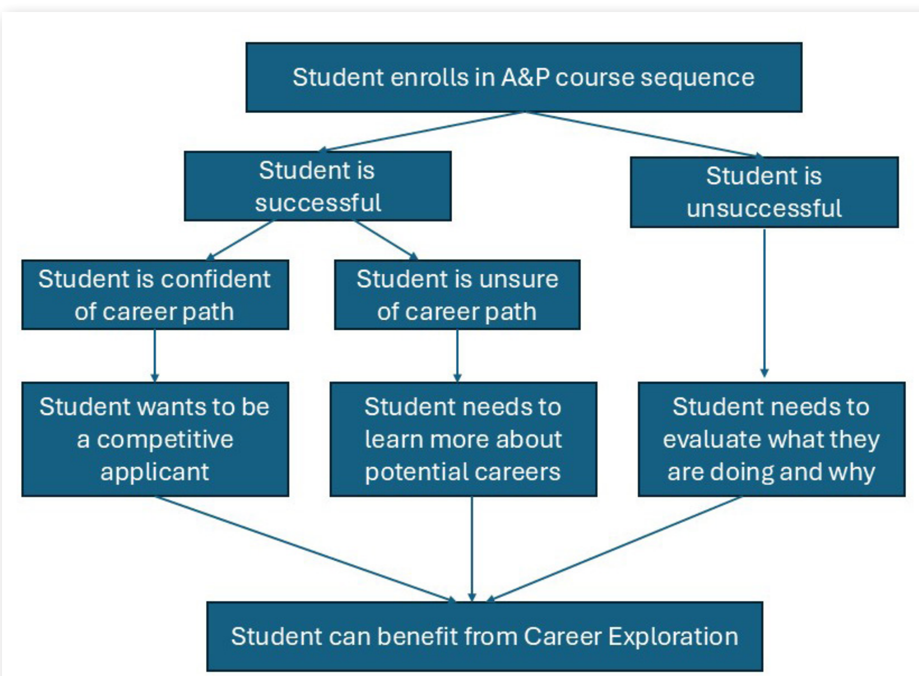

Figure 1. *All A&P students can benefit from career exploration*

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Activity Design

When we began thinking about this activity, our objectives were: 1)**;** to help students gain **knowledge** of the day-to-day experience of their choice, 2) to help students gain **confidence** that they know what they are working toward, and 3) to help students realize that they have career **options.** To meet these objectives, we originally designed the activity to focus on career options. The first questions in the activity focused on the student's current career choice. Specifically, we asked the student to describe a typical day on the job, consider what is appealing about that job, and then list 2 other similar jobs in health care as well as 2 jobs not in health care but for which a knowledge of anatomy and physiology would be useful. The subsequent questions asked students to list 3 tasks that would help them get started or continue on their chosen career path, and to find 2 shadowing or internship opportunities that would help them either progress on the path of choosing a career path and/or advancing in their path. Finally, students were asked to select one answer to the question of whether the assignment was helpful and explain their answer in two sentences. After testing this initial version of the activity in our classes during the academic year of 2023-2024, we revised and restructured it to focus more on clearly identifying where students currently are in their progression toward a career, and to clearly state their next step. To this end, in the revised version we added another section allowing students to identify their current position in a career pathway using a visual representation of the pathway and clearly state their next concrete step. Specifically, we designed a graphic showing the progression from exploring to deciding to applying for a career path (Figure 2).

Students were asked to self-identify their position on the pathway by adding a check mark, so students could clearly visualize where they currently stand and where they are going. We also asked students to identify multiple tasks that they could undertake to progress on their pathway and choose one of these tasks as their concrete "next step."

In addition, to increase clarity about the different parts of the activity, we added section headings: "About Your Career," "About Your Career Path," and "About This Assignment." We refined the wording of several questions and added language to indicate that students should list specific internship opportunities that they could apply to, and benefit from, rather than general types of relevant internships. The revised questions were organized into three sections as shown in Table 2 (Sections of Assignment).

Section	Questions
About Your Career	Describe a typical day on the job What is appealing about this job? List 2 similar jobs in health care List 2 A&P-related jobs not in health care
About Your Career Path	Indicate current position on the Career Pathway figure List 3 tasks to do to move forward Find 2 shadowing / volunteering / internships What is your very next step, and when will you take it?
About This Assignment	Was this assignment helpful? (Select + describe) Would you like follow-up in 3 months?

Table 2. *Organization of Questions into Sections of the Career Exploration Activity*

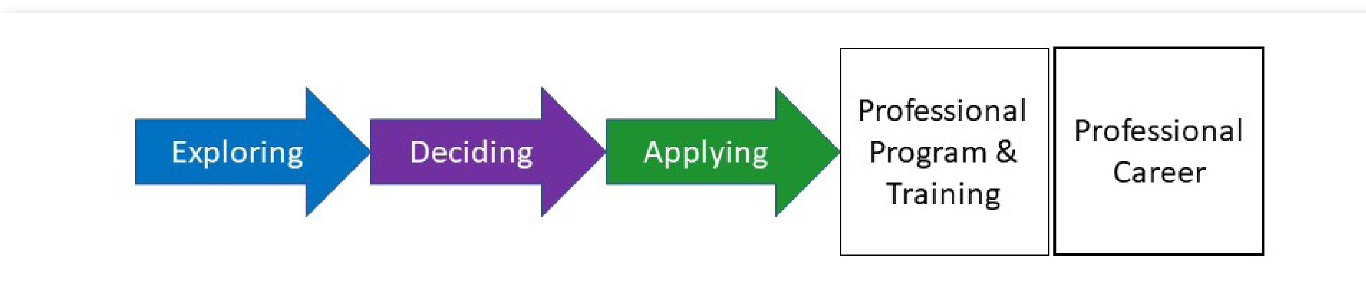

Figure 2. *Career progression pathway through explore, decide, and apply*

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We also included the following statement of purpose in the header of the assignment: "The purpose of this Extra-Credit assignment is for the student to reflect on their chosen health care field, do some research on alternate careers in health care and careers adjacent to anatomy & physiology, and consider what types of exploratory opportunities might be helpful in choosing a path or advancing along a particular path." The assignment was created as a Word file and posted to our campus Learning Management System (LMS) platform for students to download and complete. Students converted their work into a PDF for uploading to the LMS-linked Gradescope platform. The assignment (Appendix 1) was released to students in the middle of the semester with a due date towards the end of the semester, before the week of final exams. Students had 4-5 weeks to complete it and could receive a maximum of 1% bonus points added to their final course grade for on-time completion.

Collection and Analysis of Student Responses

This study was submitted to the GSU Institutional Review Board and approved as Not Human Subjects Research under Reference #385976.

Student work was scored using Gradescope during the semester and extra-credit was awarded based on complete submission. After the course ended, quantitative data was extracted from the "Statistics" page on Gradescope and qualitative responses were transferred to Excel for thematic analysis. Because the purpose of the assignment was to stimulate student career-related research and self-reflection, some parts of the activity primarily designed to prompt student reflection and research were not scored. These included the "describe your ideal job" and "day in the life of this job" questions, as well as the three specific tasks students could work on now and the two exploratory opportunities that they could apply for. Responses to these questions were not recorded nor scored. For two of the free-response questions, we analyzed student written responses using thematic analysis. These two questions were the description of the student's "Next step" in the career pathway and the explanation of why they thought the assignment was helpful. Student qualitative responses to these two questions were transferred from Gradescope into an Excel spreadsheet for thematic analysis. Thematic analysis was an iterative process where each of us looked for themes in the data. Then, we met to discuss the themes and afterward each of us coded separately the data using those themes. Finally, we discussed our coding, came to consensus, and revised the themes as necessary. Responses for both semesters were pooled together in order to increase the chance of finding representative themes in student responses.

Results

Student Majors

As shown in Table 3, approximately half of the students were on a pathway to nursing school (52%). The second largest cohort (17%) was composed of students studying biology as their major. The remaining students represented a variety of majors, mainly related to science and allied health professions.

Major	Fall 2024 (n)	Spring 2025 (n)	% of total
Biology	35	52	17%
Biomedical Sciences	2	6	2%
Chemistry	1	3	1%
Clinical Informatics	3	2	1%
Health Sciences	20	14	7%
Neuroscience	5	4	2%
Nursing	103	165	52%
Nutrition	6	3	2%
Public Health	1	3	1%
Psychology	2	0	0%
Respiratory Therapy	11	29	8%
Other	8	16	5%
Undeclared	8	11	4%

Table 3. *Majors of A&P Students*

Student Participation in the Career Exploration Activity

Students were given the opportunity to complete the career exploration activity as an optional (not required) assignment that was associated with extra-credit points (maximum 1%) toward their final course grade. A total of 64% of the students chose to complete the career exploration activity (see Table 4).

	Participating Students (n)	Total Students (n)	% Participating
Fall 2024	111	205	54%
Spring 2025	217	308	70%
Total	328	513	64%

Table 4. *A&P Student Participation in Career Exploration Assignment*

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Student Career Choice

Student responses to the first question: "Which healthcare career path are you pursuing?" were classified into a general career pathway ("Nursing", "Respiratory Therapy", "Pharmacy", etc.) as shown in Table 5. As expected, based on their majors, the most common career pathway that students reported was nursing, with 47% and 60% of students answering "Nursing" in fall 2024 and spring 2025, respectively. After nursing, the second most common career pathway for A&P2 students was to become a physician assistant (PA), at 16% and 10% for fall 2024 and spring 2025. Other career choices included a variety of allied health professions, such as respiratory therapy, nutrition, and health informatics. Physical therapy and occupational therapy were also represented, in addition to anesthesiologist assistant (AA), physician, pharmacy, dentistry, and research. Careers grouped together into "other" were a variety of unique selections including midwifery and medical sales.

Other Career Options (in Health Care or outside Health Care)

Students listed two different career options in health care that would be similar, or related, to their primary career choice, and two career options not in healthcare but for which the knowledge of anatomy and physiology is helpful. Table 6 shows an alphabetized list of student responses for both questions provided by students from one of our lecture sections in fall 2024.

CAREER PATH	Fall 2024 (n)	Fall 2024 (%)	Spring 2025 (n)	Spring 2025 (%)
Nursing	52	47%	130	60%
Respiratory Therapy	7	6%	23	11%
Nutrition	2	2%	2	1%
Health informatics	1	1%	1	0%
Physical Therapy	6	5%	6	3%
Occupational Therapy	2	2%	3	1%
Physician Assistant (PA)	18	16%	21	10%
Anesthesiologist Assistant (AA)	5	5%	6	3%
Physician (MD/DO)	5	5%	3	1%
Pharmacy	4	4%	4	2%
Dentistry	2	2%	5	2%
Research	1	1%	3	1%
Other	6	5%	11	5%
TOTAL	**111**	100%	**217**	100%

Table 5. *Student Career Choices*

Careers In Health Care	Careers not in Health Care
anesthesiologist assistant	animator & character designer
biostatistician	A&P teacher
cardiac perfusionist	athletic trainer
cardiologist	biology teacher
child life specialist	biomedical engineer
child psychologist	biomedical illustrator
clinical informatics specialist	biomedical researcher
clinical pharmacologist	chiropractor
dental assistant	cinematographer / stunt coordinator
informatics nurse	criminal investigator
labor & delivery nurse	ergonomic specialist
medical doctor (MD)	esthetician
medical scientist	fashion designer
licensed practical nurse (LPN)	fitness trainer
neonatal nurse	forensic analyst
nurse	forensic anthropologist
nurse practitioner	forensic scientist
occupational therapy (OT)	human factors specialist
oral health educator	in-home caretaker
patient care tech (PCT)	massage therapist
pediatric nurse	medical assistant
pharmaceutical sales rep	mortician
phlebotomist	nail technician
physical therapy (PT)	personal trainer
physician assistant (PA)	PE teacher
plastic surgery nurse	physical therapist
public health	Pilates instructor
radiologic technologist	research
rehab counselor	science teacher
rehab specialist	sports equipment designer
respiratory therapy	
school nurse	
sonographer	
speech therapist	
sports orthopedist	
surgeon	
surgical tech	
travel social work	
travel ultrasound tech	

Table 6: *Other Career Options*

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Student Position on Career Pathway Figure

Students placed a mark on the Career Pathways figure to indicate their current position and then wrote two sentences to explain the placement of their mark on the figure. A few students did not mark the figure with an "X" but did provide a description of their position. In these cases, we selected the appropriate category that matched their written description. In some cases, we standardized their responses. For example, if a student wrote that they had been accepted to start in nursing school the following semester, we marked them as "Professional Program", not "Applying."

As shown in Table 7, the majority of students placed themselves at "applying", with 76% in fall 2024 and 56% in spring 2025. In spring 2025, 19% of students were already accepted into a professional program, compared to only 4% in fall 2024. A similar proportion of students self-described as "deciding": 14% in fall 2024 and 19% in spring 2025. In both semesters, 5% of students classified themselves as "exploring." Five students did not respond with either "X" or a written description, so the percentages reported in Table 7 do not add up to 100%.

	Exploring	Deciding	Applying	Professional Program & Training
Fall 2024	5%	14%	76%	4%
Spring 2025	5%	19%	56%	19%

Table 7. *Student Self-Assessment of Position on Pathway: "X" Marks the Spot*

"Next Step?" - –Thematic analysis of student responses

After identifying potential next steps, we asked students to describe their "one very next step" to progress on their career path, as well as when they planned to take that next step. The "next steps" identified by students were coded using thematic analysis; identified themes are listed in Table 8 along with examples of each theme. Thematic answers were categorized into the following groupings: "Work on school now," "Get Information", "Get Experience", "Work on Application(s)", or "Prepare for Professional Program."

Students responding with answers in each category were coded, counted, and reported as the percentage of students with that response. The percentage of students who had any response in a particular category (for example, "Get Information") is reported in the column on the right. Students with multiple responses in a category were counted once. Results were as follows: 17% of students indicated that they are working on school now; 32% are getting more information about their career choice; 29% will get more experience; 36% are working on application(s), and 9% are preparing for their professional program. Students with responses in multiple categories were counted in each category. Thus, the sum of the percentage numbers in the right column is more than 100%.

"Why was it helpful?" –Thematic analysis of student explanations

Students were asked to select one response to the question of "Has this assignment helped you think concretely about your professional development goals and pathway?" In fall 2024, the choices were: "Yes, it was very helpful."; "Yes, it was helpful."; "It was OK."; "No, it was not really helpful."; or "No, it was not at all helpful." For spring 2025, we updated the potential responses as follows: "It was extremely helpful."; "It was somewhat helpful."; "It was neither helpful nor unhelpful."; "It was somewhat unhelpful."; and "It was extremely unhelpful." Because the response choices were different, we have not combined responses from the two separate semesters.

Overwhelmingly, students reported that the activity was at least somewhat helpful. In fall 2024, 46% of students selected "extremely helpful," while in spring 2025, 58% of students chose "very helpful." Students selecting "somewhat helpful" were 41% in fall 2024 and 36% in spring 2025 (Figure 3). Pooled together, over the two semesters, 302 out of 326 student responses (93%) to this question indicated that the activity was either somewhat or very/extremely helpful.

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THEME	EXAMPLE
Work on school now	"finish all of the prereqs with Bs or better" "complete my medical terms course"
Get Information	
- shadowing	"shadow at a hospital" "find optometrists to shadow"
- internship	"do an internship with one of the organizations I listed above" "learn more about internships"
- informational interview(s) / networking	"connect with Anesthesiologist assistant" "speaking with practicing pharmacists in different specialties"
- clubs / organizations / conference	"joining a professional dietetics organization" "present research at a symposium
Get Experience	
- working to get clinical hours	"gaining more experience and patient care hours" "work on getting my patient care hours"
- get a job in health care	"getting a phlebotomy job" "find a healthcare related job this summer"
- training program (CNA, MA, EMT)	"complete my Medical Assistant program" "applying for a CNA program"
- volunteer	"apply for summer volunteering" "volunteering at Best Friends Animal Society"
Work on Application(s)	
- compare schools	"deciding on which nursing school I'm going to attend" "visit nursing schools to find the best fit"
- prep / take entrance exam	"take the TEAS exam" "study and take my GRE"
- apply for school	"apply to Georgia State University's nursing school" "apply to PA programs"
- work on personal statement	"brush up my essay" "writing my personal statement"
- advisor/ fac/ LOR	"speak with my advisor" "connect with all my professors"
Prepare for professional program	"preparing for nursing school" "connect with nursing students for study habits"

Table 8. *"Next Step" Themes – terms and examples*

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THEME		Students Responding (%)	
Work on school now			**17%**
Get Information			**32%**
	shadowing	15%	
	internship	6%	
	informational interview(s) / net-working	16%	
	clubs / organizations / conference	2%	
Get Experience			**29%**
	working to get clinical hours	7%	
	get a job in health care	8%	
	training program (CNA, MA, EMT)	3%	
	volunteer	15%	
Work on Application(s)			**36%**
	compare schools	10%	
	prep / take entrance exam	14%	
	apply for school	14%	
	work on personal statement	3%	
	advisor/ fac/ LOR	5%	
Prepare for professional program			**9%**

Table 9. *Thematic Analysis of "Next Step" Responses*

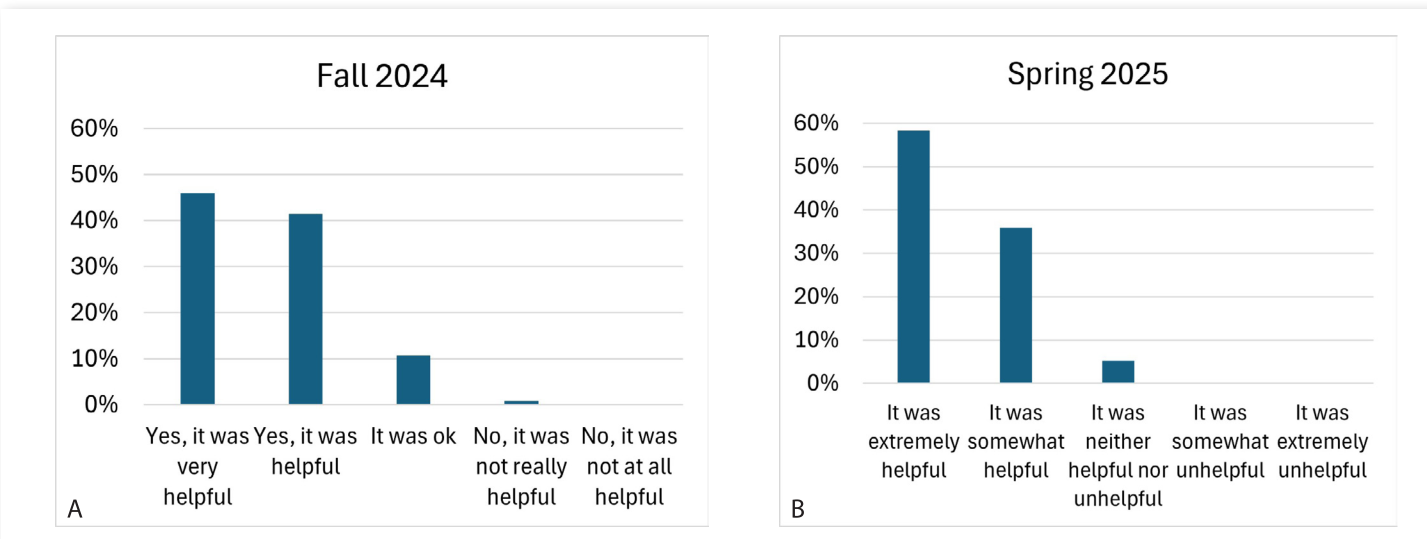

Figure 3. *Students reported whether the assignment was helpful (Panel A: Fall 2024; Panel B: Spring 2025)*

Table 10 describes the definitions of the themes coded for the responses to why students found the activity helpful. For the explanations of responses to the question, "Why was the activity helpful?", we coded the responses as described above and then groups the themes into 3 major categories: cognition-related responses, affect-related responses and behavior-related responses. Motivation was treated separately as its own category.

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	Why the activity was helpful/very helpful	Quotes: Examples of student responses
Cognition-related responses		
Self-reflection	Reflect on, think deeper about themselves and their career	"gave me a deeper look into my career path" "reflect on what I want to do" "clarify my long-term goals" "reflect on what draws me to pediatric nursing"
Alternative careers	Think about or investigate other career options different from their primary career choice	"think about other avenues other than nursing. I feel like acknowledging that can be helpful because there are many opportunities in the healthcare field that I tend to forget about" "opened my eyes to other jobs and careers" "encouraged me to carefully explore my options" "think about backup options and other related careers" "have a back up plan"
Explore career choice	Research or learn more in-depth about the job corresponding to their primary career choice	"On deeper level (. . .) explore my future nursing career" "research the responsibilities nurses have in real life" "encouraged me to research my chosen career which I may not have done before" "research about opportunities I could take to have a deeper understanding of the career I want to pursue"
New outlook on the future	Develop a new or refined perspective on their career path, and goals	"giving me a clearer sense of direction" "helped me put my future into perspective and think about things I could proactively be doing that would benefit my journey" "gave me a clearer vision of my goals " "highlighted some key steps I hadn't considered and gave me a new perspective" "allowed to me to finally make a choice on a program to attend" "made my goals feel clearer and more achievable"
Focus	Decrease the distractions, get centered, more focused on their path or goals	"how to stay focused on achieving [my goals]" "school can be blinding and a distraction from things I need to do. So this helped me realize, I need to focus on important things" "realize that I have to focus and spend less time procrastinating" "helped me point out what I needed to focus on and how to stay focused on my goals"
New insight on current stage	Develop a new or refined perception, or awareness of their current position on their career path	"reflect on what I currently stand in my pharmacy career path" "gave me insight on what my current priorities should be" "know where I currently stand in my career journey" "visualize where I am right now"
Organize thoughts	Organize their thoughts about their career goals and path	"get my thoughts organized regarding my future" "helped me organize my thoughts"
Behavior-related responses		
Plan their way forward	Map out their actions, organize their next steps into an action plan to move forward on their career path	"I created a realistic plan to gain experience" "helped me breakdown what I was going to do next" "gave me insight on the time frame I should complete these tasks" "come up with an actionable plan" "organize the steps that I need to take in order to get to my goal" "identify the steps needed to take to further my nursing journey"
Hands-on experiences	Search for concrete and relevant experiential learning activities, such as internships	"research internships, ways to get hands-on experience" "learn more about internship opportunities at hospitals" "find a couple volunteering opportunities that can be really helpful for me to be able to get more experience" "seek out both volunteer and employment opportunities" "prompted me to take concrete action towards gaining hands-on experience"
Write things down	Write down their thoughts, ideas, goals, or plans, as opposed to keep them in their mind	"have [my career path] written out (typed out) somewhere to reference back to again" "actually being able to write and plan it out helped me a lot" "write down my thoughts" "write down the answers to the questions I have every day in my head" "Writing it down helps me to visualize the steps I need to take"
Affect-related responses		
Confidence	Increase confidence in themselves and/or their path forward	"gave me a step-by-step way to move forward with confidence" "made me feel more confident (. . .) about the path I'm taking" "I now feel more confident about how to move forward with my goal" "made me confident that I am on the right track" "I feel (. . .) confident moving forward"
Reduced anxiety	Reduction in their career-related anxiety	"This assignment withheld a lot of the anxiety" "helpful in reducing the anxiety towards reaching these goals"
Motivation-related responses		
Motivation	Increase motivation to do what will help them move forward on their career path, or to think positively about their career path	"motivated me to look for real-world opportunities that align with my interests" "I feel motivated (. . .) moving forward in my journey" "motivated me to find resources that would put me in a better position" "even motivated me to be more proactive" "this assignment motivated me to never give up and continue (. . .) on my goals"

Table 10. *Themes, Definitions and Examples for "Why was it helpful?"*

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As displayed in Table 11, most of the students provided responses that were cognition- or behavior-related explanations whereas affect-related answers were minimal. A small number of responses were motivation-related (n=22; 6.7%).

Specifically, the explanations that were more cognitive in nature were more diverse than those of the other categories. The opportunity provided by the activity for self-reflection was the most frequently provided reason (n=93; 28.4%). Thinking or investigating related but alternative careers to their primary career choice (n=60; 18.3%), as well as further exploring their primary career choice (n=38; 11.6%) were other relatively frequent explanations related to the cognitive dimension. Other cognition-related answers included having gained a clearer understanding of where they currently are in their career path (n=18; 5.5%), and obtaining a new outlook or refined perspective on their path forward, including visualizing the pathway, getting a clearer sense of direction, and an increased perception that their goals were attainable or achievable (n=25; 7.6%). An increased focus (n=21; 6.4%) and more organized thoughts (n=17; 5.2%) were also mentioned as reasons why the activity was helpful.

In terms of behavior-related explanations, almost half of the students (n=151; 46%) reported that they found the activity helpful or very helpful because it helped them plan, including defining and organizing their next steps into concrete and realistic actions to move effectively forward on their career path. Searching for hands-on experiences, such as shadow or volunteer opportunities, or especially internships, that they could actually apply to were also mentioned as a helpful benefit provided by the activity (n=56; 17.1%), along with writing down their thoughts, goals or action steps (n=40; 12.2%).

Only a few affect-related responses were reported and concerned an increased confidence (n=13; 4.0%) and decreased anxiety (n=2; 0.6%). No other responses related to feelings were provided. Finally, students also reported an increased motivation to do what will help them move forward on their career path, such as look for experiential learning opportunities or resources, or simply motivation to be more proactive and to "never give up" (n=22; 6.7%). Examples of quotes taken from student responses for each of the themes described are provided in Table 10. Finally, some of the students (12%) said that they had already completed this type of career-related reflection, either on their own, or in the context of another course. Yet, they still completed the activity.

	Number of Coded Responses	% of Students (n = 328)
Cognition-related responses		
Self-reflection	93	*28.4*
Alternative careers	60	*18.3*
Explore career choice	38	*11.6*
New outlook on the future	25	*7.6*
Focus	21	*6.4*
New insight on current stage	18	*5.5*
Organize thoughts	17	*5.2*
Behavior-related responses		
Plan their way forward	151	*46.0*
Hands-on experiences	56	*17.1*
Write things down	40	*12.2*
Affect-related responses		
Confidence	13	*4.0*
Reduced anxiety	2	*0.6*
Motivation-related responses		
Motivation	22	*6.7*

Note: students may have written explanations related to several categories above, thus the total number of students does not equal 100%.

Table 11. *"Why was it helpful?" – Thematic analysis of student explanations*

continued on next page

Student Request for Follow-up

Students were asked whether they would like to receive a brief follow-up survey in three months' time, for the purpose of accountability. For both semesters, 56% of students responded "Yes". The objective of this follow-up survey was to create accountability for each student to accomplish their next step.

Success in the Course

The most immediate measure of student success in the course was the grade distribution for the course (Table 12). In fall 2024, 7% of the students earned a grade of A, whereas in spring 2025, this number was higher at 16%. For each semester, a relatively similar number of students earned grades of B (23% and 29%, for fall 2024 and spring 2025, respectively), and C (31% for both semesters). Similarly, for both semesters 5% of students withdrew ("W"). In spring 2025, more students earned grades of A and B compared to fall 2024. The fall semester was associated with more students earning a grade of D (12% versus 20% in spring 2025). DFW rates for fall 2024 were higher (38%) than for spring 2025 (24%)

	Fall 2024	Spring 2025
A (90-100)	7%	16%
B (80-89)	23%	29%
C (70-79)	31%	31%
D (60-69)	20%	12%
F <60	13%	7%
W	5%	5%
DWF	38%	24%

Table 12. *Grade Distribution for Fall 2024 and Spring 2025*

Discussion

In summary, we have developed a career exploration activity based on student self-reflection, deeper investigation of their current career choice and identification of alternate career options, self-assessment of progress toward their career goal, and identification of concrete steps to move forward. We have piloted this activity for two years, with iterative changes, and in this article, we present student responses gathered over the past academic year, in fall 2024 and spring 2025.

The overwhelming majority of students indicated that the activity was either "helpful" or "very helpful" and slightly more than half requested follow-up in three months for accountability on their progress with the next step they had identified. Some of the students indicated that they had completed this type of activity before, either on their own or in a different class, yet they still completed this career exploration activity and said that it was a good "reminder" or that they had "not thought about" some aspects, such as alternative career options. Importantly, they perceived that the activity was especially helpful in terms of actionable items, such as planning and organizing their pathway forward in particular, as well as pushing them to find concrete hands-on experience from which they can benefit. Students reported that the activity helped them think more about and explore more deeply their current career choice, as well as consider alternative options and back-up plans. Some also felt more confident or less anxious in their path forward.

Although we had predicted that students would experience increased motivation for the course, few students reported increased motivation as a benefit. This may be due in part to the fact that we did not ask students directly about motivation. In a future study, we may include specific questions about motivation factors. Then we can assess whether expressing a specific career goal which requires success in the A&P course as a means to proceed along the career pathway will increase motivation to work hard and succeed in the course. Understanding more about what motivates students to work hard in A&P would be helpful as we continue to make changes at the course level, with student success in mind. Komarraju et al. (2014) have shown that for undergraduate students in psychology, obtaining more information about their career improved career decision self-efficacy which contributed to increased motivation. We are hoping to create professional identification, which has been positively related to both extrinsic and intrinsic goals, in a study of mentoring in graduate students (Greco & Kraimer, 2020). These two studies support the possibility that through our directed exploration career activity, the students may have had a positive influence on their motivation even though only 4% reported increased motivation.

In this study, we introduced this activity to students at the midpoint of the semester with a deadline before the week of final exams. In the future, we may consider introducing this directed activity earlier in the semester to increase the likelihood of students keeping their career goal in mind throughout the semester, as identified motivation for working toward success in the course. We may also consider assigning a Career Exploration activity during the A&P1 course. In one author's opinion, the most important secondary goal of A&P (apart from the primary goal of building a foundation of A&P knowledge) is to build academic skills such as study skills and time management. Including a career exploration module and perhaps even connecting study skills and career exploration together into one module might allow for a synergistic effect on academic motivation and learning.

This study demonstrated the existence of two diverse groups of A&P students: pre-nursing early-college students versus more senior science majors headed for a professional program, such as PA or AA school. In the future, we may

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consider splitting the courses into two series, one for pre-nursing students and the second designed for upper-level science majors. This would allow us to focus on instruction at levels appropriate to the knowledge required and the level of prerequisite scientific foundation students bring to the course. Supplemental instructional resources could be tailored towards specific student populations. In the course designed for pre-nursing students, we may consider an increased emphasis on career decision making and planning. Siebert and collaborators (2022) have shown that it is possible to increase proactive career decision making skills and career choice self-efficacy in high school students through explicit training in decision-making through envisioning objectives, identifying alternatives, and comparing the alternatives. This finding supports the inclusion of this strategy into our future courses.

Our students found the career exploration activity helpful because it promoted planning. Although there are studies suggesting that career planning increases academic motivation, the connection between career planning and academic success is not well-defined (Floris et al., 2024; Küçükaydin, 2024). As we reflected on our findings, it became clear that student responses indicating that the activity helped them to "plan" might not be equivalent to a strictly defined "career planning" module. We may need to include additional questions to intentionally tease out the nature of the "plan" with more granularity and understand better what exactly is meant by having a "realistic plan." This would help us better identify how we can further support our students.

Reflection was the second most common theme of student responses as to why the activity was helpful. This makes sense, as self-analysis and self-assessment questions require students to think deeply about what they want in life, where they are now, and where they are heading. This finding aligns with other studies supporting the use of reflection to impact student career readiness and motivation. For example, career exploration and self-reflection positively predicted career adaptability and subjective well-being in undergraduate students (Ran et al., 2023). Similarly, career exploration was also associated with career decidedness and perceived employability (Kleine et al., 2021) and setting goals can have an impact on academic achievement (Travers et al., 2015).

Reflection has also been shown to decrease anxiety and negative emotions and increase the confidence of nursing students (Del Vecchio et al., 2024). Reflection incorporated as part of the clinical curriculum has been shown to enhance self-discovery and self-awareness, with a positive effect on the emotional well-being of nursing students transitioning to practicing nurses (Bowers et al., 2025). Nursing students primarily choose nursing as a profession due to a desire to contribute to society and have a positive impact on people (Ait Ali et al., 2024). Understanding that pre-nursing students have altruistic tendencies and the desire to serve places emotional well-being and belonging as additional factors relevant to motivating students, and this can be a reason on its own to encourage student reflection. Reflection can influence students at the affective level rather than the cognitive level (Cavilla, 2017) which supports the use of reflection as a learning tool even if it is hard to demonstrate an effect on immediate academic success. This suggests that intentionally incorporating affect-related factors of motivation within our future career exploration activities could be worthwhile.

Written reflection can also promote critical thinking skills (Klaeson et al., 2017). Critical thinking skills are essential for academic success and can even predict academic performance in college students (Ren et al., 2020). Including reflection as part of the later clinical curriculum can also lead to increased clinical competency (Bowers et., 2025). Taken together, these studies suggest that incorporating reflection into the pre-nursing curriculum could lay the foundation for a reflective practice that could lead to positive outcomes in the lives of future practicing nurses.

In summary, we set out to remind students of their purpose and motivate them to succeed in the course and move forward in their progress toward their chosen career. Over multiple semesters, we have seen an overwhelmingly positive student response to this Career Exploration Activity, as it has been well-received by students who report that it is helpful. As we move forward with this activity, we hope to strengthen the ties between career exploration and motivation. As we deepen our understanding of the factors that motivate students to succeed in A&P, we can promote their college-to-career transition and ultimately, their career success.

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Appendix 1. Career Exploration Extra Credit Assignment

The purpose of this extra credit assignment is for the student to reflect on their chosen healthcare field, consider options, and plan the next steps to move forward on their chosen career path.

Student Name: ______________________

<u>ABOUT YOUR CAREER PLAN:</u>

Which healthcare career path are you pursuing?

Describe the job you hope to have after you finish your education and/or training.

Describe a typical work day in this job.

What is appealing to you about this job?

Now do some research and list 2 other jobs that you could pursue, that would provide you with similar opportunities for type of work, level of compensation, and other personal benefits.

1.

2.

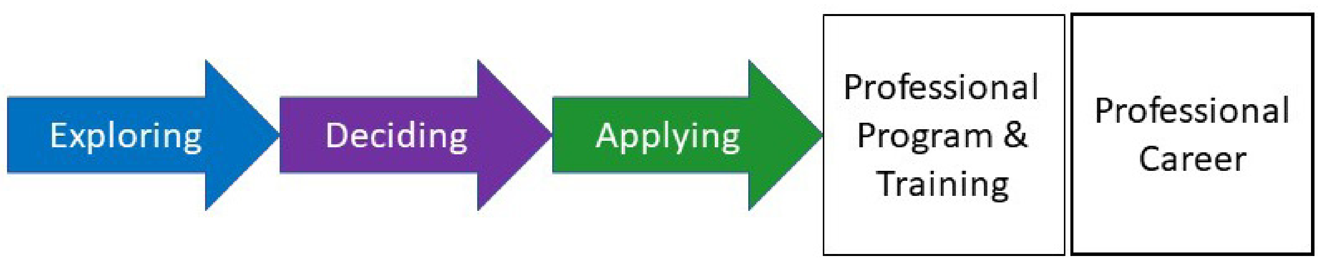
Find 2 other professions, <u>not in healthcare</u>, where a knowledge of and affinity for anatomy & physiology would be useful.

1.

2.

<u>ABOUT YOUR CAREER PATH:</u>

At this point in your career journey, you might be <u>exploring</u> options; <u>deciding</u> on a path; or <u>applying</u> for a specific program. Please mark the figure below to indicate where you currently are on this path.



Please write 2 sentences to explain the placement of your mark on the figure.

How are you going to move forward? List <u>3 specific tasks</u> that you could work on now. This could be areas to learn more about; questions to answer; people to talk with; working on your resume; anything that will help you take the next step in your career path.

1.

2.

3.

continued on next page

It's often helpful to get hands-on experience in your chosen field before starting your professional program. Find 2 exploratory shadowing, volunteering, or internship opportunities that you can pursue that are currently accepting applications.

1.

2.

Now you have identified where you are and you have listed several ways to move forward. With this in mind, what is the one very next step for you on your career path? And when are you going to take this step?

ABOUT THIS ASSIGNMENT:

Has this assignment helped you think concretely about your professional development goals and pathway? (mark one selection)

___ It was extremely helpful.

___ It was somewhat helpful.

___ It was neither helpful nor unhelpful.

___ It was somewhat unhelpful.

___ It was extremely unhelpful.

Briefly describe why you chose this answer (1-3 sentences).

Would you like us to provide you accountability by checking in on your progress with a brief follow-up survey in 3 months?

_____ Yes

_____ No

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Testosterone and the Risk Factors Implicated in its Steady Decline

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Abstract

Testosterone is a vital hormone for development, metabolism, and overall health in both males and females. Beyond reproductive function, testosterone contributes to bone and muscle integrity, cardiovascular health, cognition, and mood regulation. Over recent decades, population-based studies have documented a steady decline in testosterone levels in men, coinciding with rising infertility and metabolic disorders. This trend likely reflects the combined influence of environmental endocrine disruptors, reduced physical activity, inadequate sleep, and socioeconomic stress. This study measured salivary testosterone levels in young adult males from Erie, Pennsylvania, and examined its associations with lifestyle, activity, sleep duration, body weight, and economic status. The results highlight how behavioral, biological, and environmental factors interact to influence endocrine function. From teaching perspective, these findings can serve as a case study for health science students learning about the endocrine system, illustrating how lifestyle and socioeconomic factors contribute to hormonal variation. A deeper understanding of these interactions may help future healthcare professionals design prevention strategies and incorporate lifestyle modification into clinical care of patients with low testosterone. https://doi.org/10.21692/haps.2026.007

Key words: salivary testosterone, ELISA, lifestyle, socioeconomic factors, hormonal regulation

Introduction

Testosterone is a vital regulatory hormone that influences a wide range of physiological processes in human males and females. It plays key roles in development, reproduction, maintenance of muscle and bone mass, cardiovascular health, cognition, and sexual health (Rojas-Zambrano et al., 2025). Additionally, testosterone has been associated with psychological and behavioral regulation, influencing personality traits and emotional stability (Dabbs & Morris, 1990). Over recent decades, multiple studies have reported a significant decline in testosterone levels among men (Nyante et al., 2012; Perheentupa et al., 2013). Travison et al. (2007) reported a generational decrease in serum testosterone that cannot be explained by aging alone, suggesting contributions from environmental, lifestyle, and psychological factors. A recent report indicated that even younger men also exhibit lower testosterone levels than previous generations (Lokeshwar et al., 2021). This downward trend raises concerns for public health, as low testosterone (hypogonadism) has been linked to infertility, obesity, cardiovascular disease, muscle atrophy, and cognitive decline (Cohen et al., 2020; Fui et al., 2014).

Although multiple studies have identified a decline in serum testosterone levels among men over the past few decades, the underlying causes remain uncertain (Feldman et al., 2002). Factors such as obesity, sedentary lifestyles, sleep deprivation, poor diet, and exposure to endocrine-disrupting chemicals have been associated with lower testosterone levels, though their relative contributions are not well defined (Fui et al., 2014). Additionally, socioeconomic conditions, including financial stress, limited access to nutritious food, and reduced opportunities for recreation, may interact with lifestyle habits to influence endocrine function. Addressing these relationships is critical for clarifying how behavioral and environmental variables collectively contribute to the observed population-level decline in testosterone.

This study is relevant to health professional students enrolled in anatomy and physiology course because it allows students to connect the foundational endocrine concepts, such as endocrine system regulation and hormonal feedback, to lifestyle, behavior, and environment factors and how they could impact hormone levels and function. By examining

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how testosterone levels vary significantly with weight, height, sleep, physical activity, and socioeconomic factors, students can better understand the complex physiological interactions involved in hormonal balance and male reproductive health. When these students enter health care fields later in life, a deeper understanding of this could help them develop preventative measures or integrate lifestyle modification into their treatment plans of patients with low testosterone levels.

Given the observed decline in testosterone across male birth cohorts and the uncertainty surrounding its determinants, this study seeks how anthropometric, behavioral, and socioeconomic factors relate to testosterone levels in young men. Specifically, we examined possible associations between salivary testosterone and (1) weight, (2) height, (3) sleep, (5) diet quality, (6) financial status, and (7) parental education. We hypothesized that higher body weight (as a proxy for adiposity) and advancing age would be associated with lower salivary testosterone concentrations, whereas greater physical activity, adequate sleep, and higher socioeconomic standing would be associated with higher testosterone levels. These expectations were based on prior findings linking stress, energy balance, and metabolic health to hormonal regulation.

Materials and Methods

Participants

This cross-sectional study was conducted at Gannon University during the 2024 academic year. Fifty-nine male students, aged 18-25 years (mean = 20.4 ± 1.1), voluntarily provided saliva samples and completed a lifestyle questionnaire (Appendix 1) assessing potential influences on testosterone levels. All participants were healthy, had no known endocrine disorders, and were not using hormone-based medications at the time of the study. Participation was open to all eligible students without exclusion, and informed consent was obtained from each participant. The study was reviewed and approved by the Gannon University Institutional Review Board (Approval No. GUIRB-2024-1-7199)

Questionnaire

Participants completed a 25-item self-administered questionnaire (Appendix 1) designed to assess lifestyle and health factors potentially influencing testosterone levels. The survey included five sections covering general health, diet, exercise, sleep, and daily lifestyle habits. Specific questions were asked to estimate their weekly activity levels, average hours of sleep, and typical dietary balance, including the frequency of fruit and vegetable consumption and supplement use. Participants self-classified their activity level (Lightly Active, Moderately Active, Active, or Highly Active) based on overall weekly exercise habits. The survey did not quantify exercise frequency (sessions per week), duration (minutes per session), or training modality (aerobic, resistance, endurance, or flexibility training). Therefore, activity categories reflect perceived overall activity level rather than objectively measured exercise volume or intensity. The questionnaire was completed on paper, and participants were given time until their samples were tested to complete the survey. They were instructed to respond honestly, and all responses were kept confidential. Demographic and background data were collected solely to characterize the sample population and were not used in statistical comparisons to preserve participant confidentiality.

Sample Collection

Saliva samples were collected in 1.5 mL sterile collection tubes after participants brushed their teeth and rinsed with water. To minimize contamination, participants were instructed to avoid eating or drinking before collection and to provide approximately 1 mL of saliva. All samples were collected between 8:00 AM and 10:00 AM to control for diurnal variation in testosterone levels. A minimum of 0.8 mL of saliva was collected from each participant for analysis.

Following collection, samples were brought to the laboratory and analyzed the same day. Saliva samples were centrifuged at room temperature for 5 minutes at 300 rpm to remove any food debris and to clarify the supernatant.

Testosterone Assay

Salivary testosterone concentrations were quantified using a commercially available enzyme-linked immunosorbent assay (ELISA) kit (DRG International Inc., NJ, USA). The assay operates on a competitive immunoassay principle, where endogenous testosterone in the saliva samples competes with a fixed quantity of enzyme-labeled testosterone for antibody binding sites within the microplate wells. Following incubation and washing, a colorimetric substrate was added, and absorbance was measured at 450 nm using a microplate reader.

Testosterone concentrations were calculated by comparing the absorbance values of the samples to the standard curve generated from the reference standards (0-1000 pg/mL). All samples were run in duplicate, and negative controls were included in each assay to ensure accuracy and reproducibility of results.

Data Analysis

All statistical analyses were performed using Microsoft Excel. Because the dataset did not meet normality assumptions, nonparametric Kruskal-Wallis were used to compare mean salivary testosterone levels across categorical variables, including weight range, age, body type, activity level, and socioeconomic status. Pairwise post hoc comparisons were conducted with Bonferroni corrections, when appropriate, and statistical significance was set at $p < 0.05$. Each participant provided a single saliva sample, which was analyzed independently; thus, results represent point estimates rather than repeated measures. A total of 1,201

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individual data points were analyzed across 23 variables. Future studies may benefit from the use of multivariate models to better account for confounding factors such as age, weight, and socioeconomic status.

To improve statistical robustness and address small subgroup sizes, categorical variables, such as age, body weight, sleep duration and economic status, were consolidated into groups so that each comparison group contained a minimum of five participants. Age was classified into three groups (18–19 years, 20–21 years, and 22–25 years). Weight was consolidated into four groups (121–150 lbs, 151–170 lbs, 171–190 lbs, and 191–250 lbs). Sleep duration categorization excluded the single participant reporting less than 5 hours, and grouped the remaining participants into two groups (6–8 hours and 8–10 hours). Physical activity was consolidated into two groups: Lower Activity and Higher Activity. Economic status category into three groups: Lower Income, Middle Income, and Upper Income. These adjustments were made to ensure sufficient group sizes for nonparametric statistical comparison and to enhance the reliability of inferential analyses.

Results

The study population consisted of 59 male participants between ages 18 and 25 years (Median = 20; interquartile range = 19-21). Approximately 54% reported regular use of at least one supplement, 36% classified themselves as highly active, 47% reported a height exceeding six feet, 41% weighed between 161and 180 pounds, and 19% reported sleeping an average of eight to nine hours per night. These categorical groupings were used in subsequent analyses to evaluate associations between lifestyle factors and salivary testosterone levels. The outlier data points in each category are determined by using box plots and are not reported.

Age

To evaluate age-related variations in testosterone levels, participants were divided into three groups, 18-19 years, 20-21 years and 22-25 years. A Kruskal-Wallis H test indicated a statistically significant difference in testosterone values across age groups (H (2) = 9.26, $p = 0.0098$), suggesting that testosterone values varied with age.

Figure 1 illustrates the mean salivary testosterone levels with standard deviations for each age group (n=56). Group sizes were as follows: age 18-19 (n = 14), age 20-21 (n = 34), age 22-25 (n = 8). Outliers were identified and removed using a box plot method prior to statistical analysis.

Testosterone concentrations demonstrated a declining trend with increasing age categories, with the highest mean values of testosterone observed in the youngest group and lower mean values observed in the older groups. Post hoc pairwise comparisons using Dunn's test with Bonferroni correction confirmed that testosterone levels in the 18–19-year group were significantly higher than those in the 22- and 25-year groups ($p < 0.05$). These findings indicated an inverse relationship between age and testosterone concentration within this young adult sample.

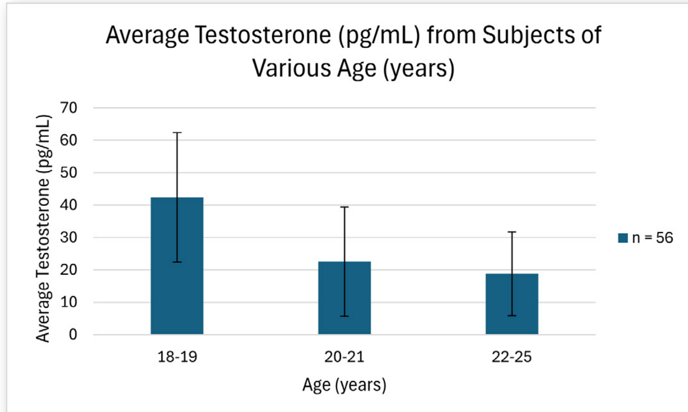

Figure 1. *Average testosterone (pg/mL) from subjects of various age groups (years)*

Weight

To evaluate the relationship between weight and salivary testosterone levels, participants were divided into four weight categories ranging from 121-250 lbs. A Kruskal-Wallis H test indicated a statistically significant difference in testosterone concentrations across these weight groups (H (3) = 11.20, $p = 0.011$), demonstrating that testosterone levels varied significantly by body weight within the sample.

Figure 2 illustrates the mean salivary testosterone concentrations with standard deviations for each weight category (n=59). Group sizes were as follows: 121-150 lbs (n = 9), 151-170 lbs (n = 15), 171-190 lbs (n = 29), 191-250 lbs (n = 6).

Testosterone levels demonstrated a consistent decline with increasing body weight, with participants in the 121–150 lb group exhibiting the highest mean testosterone levels and those in the 191–250 lb group displaying the lowest. Post hoc pairwise comparisons using Dunn's test with Bonferroni correction revealed that testosterone levels in the 121–150 lb group were significantly higher than those in the 191–250 lb group ($p < 0.05$). These results indicated an inverse association between body weight and testosterone levels, suggesting that greater body mass corresponded to lower salivary testosterone within this sample.

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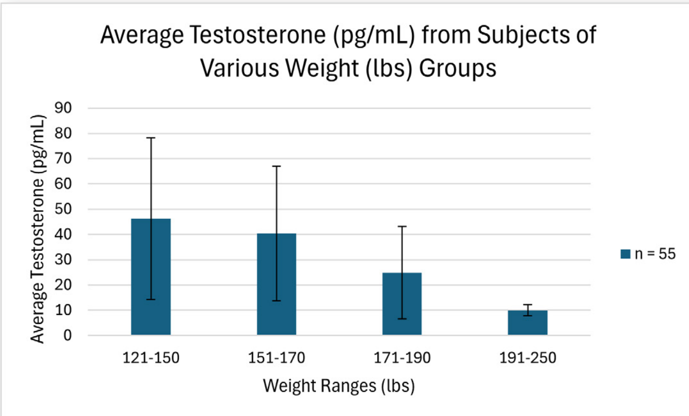

Figure 2. *Average testosterone (pg/mL) from subjects in various weight (lbs) groups*

Sleep

To evaluate the relationship between sleep duration and testosterone levels, participants were grouped into two self-reported sleep categories: 6-8 hours, and 8-10 hours per night. A Kruskal-Wallis H test revealed a statistically significant difference in salivary testosterone concentrations across these groups (H (1) = 8.18, $p = 0.0042$), indicating that testosterone concentrations varied according to reported sleep duration.

Figure 3 presents the mean salivary testosterone levels with standard deviations for each self-reported sleep group (n=55). Group sizes were as follows: 6-8 hours (n = 47), and 8-10 hours (n = 8). The <5-hour group was omitted because it contained only one participant, resulting in a standard deviation of zero and non-significant statistical value. Outliers were identified and removed using a box plot prior to analysis. Testosterone concentrations were highest among individuals reporting 6-8 hours of sleep per night and lower in longer sleep group. Post hoc pairwise comparisons using Dunn's test with Bonferroni correction indicated that individuals in the 6-8-hour group were significantly higher than those in the 8-10-hour group ($p < 0.05$). These results suggest that moderate sleep duration was associated with higher salivary testosterone within this cohort.

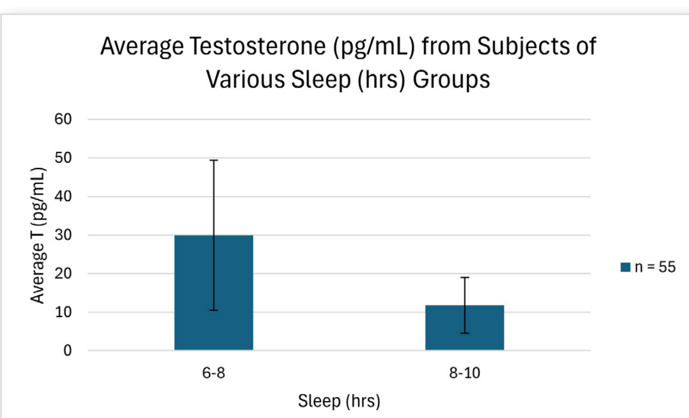

Figure 3. *Average testosterone (pg/mL) from subjects in various sleep (hrs) groups*

Exercise

To assess the relationship between physical activity and testosterone levels, the participants were divided into two self-reported activity groups: Lower Active, and Higher Active. A Kruskal-Wallis H test revealed no statistically significant difference in salivary testosterone between these activity groups (H (2) = 2.095, $p = 0.145$), suggesting that testosterone concentrations did not vary according to self-reported activity classification within this cohort.

Figure 4 displays the mean salivary testosterone levels with standard deviations for each self-reported activity group (n = 56). Group sizes were as follows: Lower Activity (n = 14), Higher Activity (n = 42). Outliers were identified and removed using a box plot method prior to analysis. Although minor differences in mean values were observed descriptively, these differences were not statistically significant. Because activity level was self-reported categorically and not quantified by frequency, duration, intensity, or training modality, these findings reflect general activity classification rather than precise exercise load. Additionally, limited variability in reported exercise patterns within this sample may have reduced the ability to detect meaningful associations.

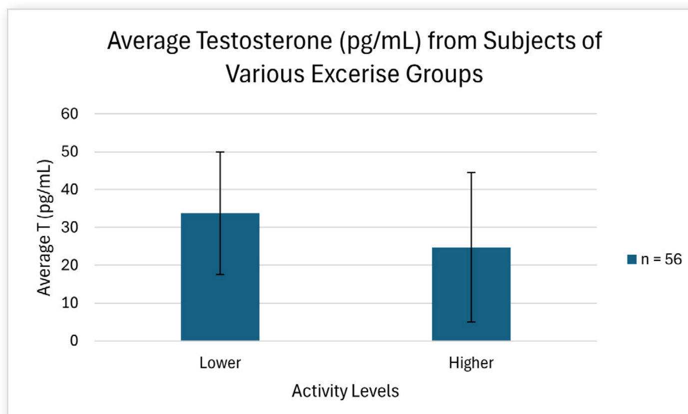

Figure 4. *Average testosterone (pg/mL) from subjects in various exercise groups*

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Economic Status

To evaluate the relation between economic status and salivary testosterone levels, participants were divided into three self-reported income categories: Lower Income, Middle Income, and Higher Income. A Kruskal-Wallis H test Revealed a statistically significant difference in testosterone concentration among these groups ($H(2) = 4.679$, $p = 0.456$), suggesting that testosterone levels did not vary significantly based on reported economic status within this sample.

Figure 5 presents the mean salivary testosterone levels with standard deviations for each self-reported economic status group (n=57). Group sizes were as follows: Lower Income (n = 8), Middle Income (n = 24), Higher Income (n = 25). Outliers were identified and removed using a box-plot method prior to analysis. Although descriptive variation was present between groups, these differences were not statistically significant. Therefore, within this cohort, self-reported economic status was not significantly associated with salivary testosterone concentrations.

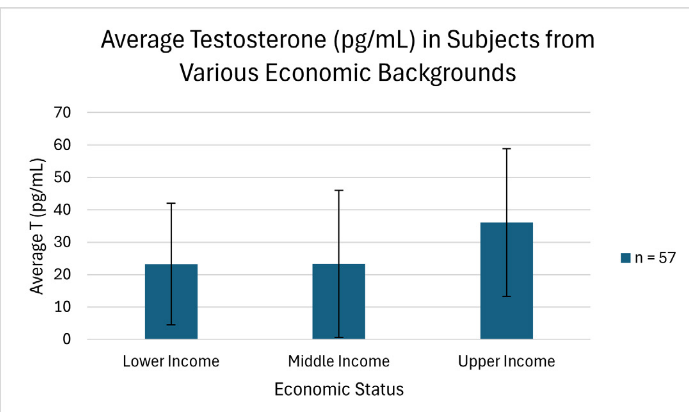

Figure 5. *Average testosterone (pg/mL) in subjects from various economic backgrounds*

Discussion

In this study salivary testosterone levels were measured in young adult males from Erie, PA to evaluate how anthropometric, behavioral, and socioeconomic factors related to hormonal variation. Independent analyses were conducted on age, body weight, sleep duration, physical activity, economic status, and height. The observations of this study align with previous reports that age and weight are inversely associated with testosterone concentration (Chuang et al., 2017). Overall, significant associations were identified between testosterone levels and several anthropometric, lifestyle and socioeconomic variables, including age, weight, and sleep duration. In contrast, economic status, physical activity levels, body type, parental education, and supplement use did not demonstrate statistically significant relationships with testosterone. These results suggest that both biological and environmental influences contribute to variation in testosterone expression among young adult men.

Consistent with existing literature, the present findings demonstrate an inverse relationship between age and testosterone levels, even within the narrow age range of 18–25 years (Feldman et al., 2002). Although testosterone typically declines gradually with advancing age, the decrease observed in this young cohort suggests that lifestyle or environmental factors may contribute to early hormonal variation (Travison et al., 2007).

Likewise, in this study an inverse correlation between body weight and testosterone concentration was identified, aligning with prior studies that link greater adiposity to reduced endocrine activity (Okobie et al., 2024; Su et al., 2023). This association is thought to result, in part, from the conversion of testosterone to estrogen by the enzyme aromatase in adipose tissue (Chuang et al., 2017). Although body weight was used as an accessible anthropometric measure in this study, BMI or direct measures of adiposity may provide more precise insight into the relationship between body composition and testosterone levels. Because weight alone does not distinguish between fat and muscle mass, further studies incorporating direct measures of body composition may help in understanding this relationship.

Sleep duration also appeared to play an important role in changes in testosterone levels (Su et al, 2021). In this study, participants who reported 6–8 hours per night of sleep had significantly higher salivary testosterone concentrations than those reporting longer durations (and shorter duration- not reported). Although sleep deprivation is well-documented to suppress testosterone synthesis (Axelsson et al., 2005), if lower levels were observed in individuals sleeping 8–10 hours, this may point to underlying health issues, lower sleep quality, or other unmeasured behavioral factors. These results, based on self-reported sleep duration, highlight the importance of maintaining regular, optimal sleep schedules and warrant further investigation using objective sleep measures.

In this study, physical activity displayed a generally negative association, with concentrations decreasing in higher activity level group. Because activity level was self-reported and not quantified by exercise frequency, duration, or modality, it is not possible to determine whether participants in the "Highly Active" group engaged in prolonged endurance training comparable to the populations described by Hooper et al., (2018) or Hackney (2020). Those studies reported testosterone suppression primarily in athletes exposed to sustained high-volume or high-intensity training loads. The lower testosterone levels observed in the highly active group in the present study may reflect temporary hormonal suppression due to training stress, insufficient recovery, nutritional imbalance, or psychosocial stress; however,

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this interpretation remains speculative without objective measures of exercise intensity. Future studies incorporating detailed exercise metrics and recovery assessments would help clarify whether the observed pattern reflects adaptive endocrine regulation or transient overtraining effects.

In this study, economic status was found to be not significantly associated with testosterone concentrations, with little differences observed across income categories. Studies indicate a correlation between higher socioeconomic position and higher testosterone levels (Hughes and Kumari, 2019). In this study, there was no consistent linear pattern observed, and these findings suggest that socioeconomic factors may influence hormonal balance through complex pathways involving nutrition, psychological stress, healthcare access, and recreational opportunities (Harrison et al., 2021). However, within this relatively homogeneous university population, economic status did not show a measurable relationship with salivary testosterone. These findings underscore the importance of sample composition and variability when interpreting socioeconomic associations.

Height did not show a significant correlation with testosterone concentrations. Although height reflects developmental hormonal influences during puberty, it may not serve as a reliable indicator of current testosterone levels in adulthood. Participants were categorized into three height groups (short, medium, and tall) based on distribution observed in a box plot. A Kruskal-Wallis H test revealed no statistically significant differences among the groups, indicating that height did not meaningfully influence testosterone variability in this sample. Similarly, neither parental education level nor supplement use showed any significant associations with testosterone, suggesting that these factors may exert minimal or indirect effects on other lifestyle behaviors.

This study reinforces the importance of integrating real-world data into anatomy and physiology education. For example, these findings can support classroom discussions per lab modules on hormonal feedback loops, effects of lifestyle and behavior on the levels of hormones and thus health outcomes associated with hormonal imbalance. Students can connect classroom knowledge about hormone production, regulation, and feedback mechanisms to contemporary physiological issues facing young adult populations such as obesity and insomnia.

This study contributes to the growing body of evidence suggesting that hormonal health is influenced by the combined effects of modifiable lifestyle and socioeconomic factors. Psychological well-being may also play a role, as prior research has linked mental health status to free testosterone concentrations (Berglund et al., 2011). Nevertheless, the cross-sectional design of this study limits causal interpretation. The relatively small and demographically homogeneous sample further restricts generalizability beyond this university population. Additionally, the use of self-reported behavioral data obtained from questionnaire introduces potential recall and reporting biases that may affect the accuracy of observed associations.

Future research aims to replicate and expand upon these findings using larger, more diverse populations and longitudinal or interventional study designs to help clarify causal relationships. Incorporating objective measures of lifestyle factors, such as actigraphy for sleep, accelerometry for physical activity, and biochemical monitoring of hormonal fluctuations, would improve precision and reduce reliance on self-reported data. Additionally, assessing environmental exposures and psychosocial stressors could further elucidate the multifactorial determinants of testosterone regulation in young men.

Conclusions

In summary, this study identified significant associations between salivary testosterone levels and several lifestyle and socioeconomic variables, including age, weight, and sleep duration. Activity levels, economic status, height, body type, parental education, and supplement use did not demonstrate significant associations with testosterone concentration. Testosterone levels generally decreased with increasing age and weight, whereas moderate sleep duration was associated with higher concentrations. Although descriptive differences were observed across activity and economic groups, these variations did not reach statistical significance. These findings highlight the multifactorial nature of testosterone regulation and underscore the influence of both biological and environmental factors on hormonal health in young men.

These findings serve as a powerful teaching tool in anatomy and physiology courses. They offer concrete, real-world examples of how hormonal regulation, particularly testosterone, a key male sex hormone, interacts with lifestyle and socioeconomic factors. Educators can use this research to reinforce core physiological concepts such as endocrine feedback loops, hormonal synthesis and function, circadian rhythms and behavior influence on the hormone release.

In future studies, we will incorporate larger and more diverse participant samples to enhance the generalizability of these findings. Expanding recruitment across broader age ranges, ethnic backgrounds, and socioeconomic strata would allow for more detailed subgroup analyses and clarify whether the observed associations remain consistent across populations or are influenced by specific demographic factors.

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Appendix 1. Testosterone Research Survey

Name: ____ Email: ____________________________________

1. Age: ______

2. Height: _____ (ft) ______ (in)

3. Weight: (Please circle one only)

-90lbs	111-120lbs	141-150lbs	171-180lbs	201-210lbs	231-240lbs
91-100lbs	121-130lbs	151-160lbs	181-190 bs	211-220lbs	241-250lbs
101-110lbs	131-140lbs	161-170lbs	191-200lbs	221-230lbs	250+lbs

4. Gender assigned at birth:

☐ Male

☐ Female

☐ Other: ____________________________

5. What gender do you identify as:

☐ Male

☐ Female

☐ Other: _____________________________

6. Have you been diagnosed with any disease or autoimmune disorder?

☐ Heart Disease

☐ Cancer

☐ Thyroid disease

☐ Celiac Disease

☐ Crohne’s Disease

☐ Ulcerative Colitis

☐ Diabetes

☐ Reproductive Issues

☐ Other: __________________________________

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<u>Diet</u>: (Please check one only)

7. How often do you typically eat balanced meals?

- ☐ Never
- ☐ 1-2 times per week
- ☐ 3-4 times per week
- ☐ 5-6 times per week
- ☐ Every Day

8. How often do you consume fast food?

- ☐ Never
- ☐ A few times per year
- ☐ A few times per month
- ☐ A few times per week
- ☐ Every Day

9. What would you classify your diet as?

- ☐ Omnivore ((Plant + Meat diet)
- ☐ Carnivore (Meat only diet)
- ☐ Herbivore (Plant only diet)
- ☐ Vegan (Plant-based diet, excluding animal products)
- ☐ Vegetarian (Plant-based diet, including some animal products)
- ☐ Pescatarian (Fish-based diet)
- ☐ Other: ________________________

10. Do you take any supplements or vitamins on a regular basis?

- ☐ Vitamin A supplement
- ☐ Vitamin B supplement
- ☐ Vitamin C supplement
- ☐ Vitamin D supplement
- ☐ Vitamin E supplement
- ☐ Vitamin K supplement
- ☐ Multivitamin supplement
- ☐ Iron
- ☐ Calcium
- ☐ Magnesium
- ☐ Potassium
- ☐ Zinc
- ☐ Antioxidants
- ☐ Other: _________________________

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11. How often do you consume vegetables?
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

12. How often do you consume fruits?
- ☐ Never
- ☐ Rarely
- ☐ Sometimes
- ☐ Often
- ☐ Always

13. How many meals do you have per day?
- ☐ No full meals
- ☐ 1 meal per day
- ☐ 2 meals per day
- ☐ 3 meals per day
- ☐ More than 3 meals per day

Exercise: (Please check one only)

14. How would you describe your body build?
- ☐ Ectomorph (Thin, lean build fast metabolism)
- ☐ Mesomorph (Well-built body with average muscle buildup)
- ☐ Endomorph (A soft, round physique with a high body fat percentage)

15. On a typical day, how would you describe your activity levels?
- ☐ Sedentary
- ☐ Slightly active
- ☐ Moderately active
- ☐ Highly active
- ☐ Other: ___________________________

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16. How many times a week do you exercise?
- ☐ Never
- ☐ Once a week
- ☐ Twice a week
- ☐ 3 times per week
- ☐ 4 times per week
- ☐ 5 times per week
- ☐ 6 times per week
- ☐ Every Day

17. How long do you typically exercise for?
- ☐ 0 to 30 minutes
- ☐ 31-60 minutes
- ☐ 61-90 minutes
- ☐ 91-120 minutes
- ☐ 121+ minutes

18. How would you describe the exercise?
- ☐ Sedentary (Not much physical activity)
- ☐ Aerobic Fitness (Examples; Sprinting, swimming, etc.)
- ☐ Strength Training (Examples; Lifting, Push-ups, Planks, etc.)
- ☐ Endurance Training (Long-distance running, Cycling, etc.)
- ☐ Flexibility Fitness (Yoga, Stretching, etc.)
- ☐ Other: ______________________________

19. Do you participate in any sports?
- ☐ Yes (If so, what sport) ____________________________
- ☐ No

Sleep: (please check one only)

20. How many hours of sleep do you typically get per day?
- ☐ 0-2 hours
- ☐ 2-4 hours
- ☐ 4-6 hours
- ☐ 6-8 hours
- ☐ 8-10 hours
- ☐ 10+ hours

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21. How would you describe your sleep?
- ☐ Very bad
- ☐ Bad
- ☐ Okay
- ☐ Good
- ☐ Very good

22. During a typical week, on average how many days do you take a nap and for how long?
- ☐ 0 days
- ☐ 1-2 days
- ☐ 3-4 days
- ☐ 5-6 days
- ☐ 7 days
- ☐ Length of time: ___________________

Lifestyle (please check one only)

23. How would you describe your financial background/household income?
- ☐ Low-income
- ☐ Lower Middle-class
- ☐ Upper Middle-class
- ☐ Affluent

24. Which country/state are you from?
- ☐ In the US (if so, which state) ___________________________
- ☐ Outside of the US (if so, which country) _______________________________

25. What is the highest education level of your parents?
- ☐ Some high school
- ☐ High school
- ☐ Some college
- ☐ College
- ☐ Some post college
- ☐ Graduate

26. Would you like to receive your testosterone level?
- ☐ Yes (If so, please write your email here) ____
- ☐ No

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CURRENT TOPICS

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Learning Outcomes, Competencies, Learning Goals, and Core Concepts. Oh My

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Abstract

Anatomy and Physiology (A&P) is a foundational, yet notoriously content-dense, course in health sciences curricula. While teaching and learning of A&P can be supported by clearly defined learning outcomes, the terminology surrounding this can be confusing. Educators often grapple with the challenge of designing courses that move beyond rote memorization to foster deep, applicable understanding. This challenge is compounded by the erroneous interchanging of the following curricular terms: Learning Goals, Learning Outcomes, Competencies, and Core Concepts. While related, these terms represent distinct, hierarchical levels of educational design that serve different purposes. By understanding their uniqueness and interplay, educators can design more coherent and effective A&P courses that prepare students for future academic and professional success. https://doi.org/10.21692/haps.2026.008

Key words: anatomy and physiology, curriculum, instruction, educational design

Introduction

The volume of information in any anatomy, physiology, or combined anatomy and physiology (A&P) course can be overwhelming for both students and instructors (Brown et al., 2017; Cheung et al., 2021; Tripp et al., 2024). To reduce the likelihood of the instructor or student being overwhelmed, there is a temptation to adopt a "march through the systems" approach to covering the content (Behrendt et al., 2020; Brashinger, 2017; Britson et al., 2023; Tripp et al., 2024), in which success is often measured by a student's ability to recall a vast number of anatomical terms and physiological processes in lieu of applying critical thinking skills to analyze that information to infer an appropriate conclusion (Crowther et al., 2024; Silldorff & Robinson, 2023).

The key to escaping the "content trap" lies in intentional and structured curriculum design. Educators from K-12 through higher educational and professional training are tasked with designing curricula that are not only rich in content but also demonstrably effective for long term retention (Crowther et al., 2024; Davis & Autin, 2020; Finn et al., 2019; Graff, 2011; Human Anatomy & Physiology Society, 2020a; Hopper, 2017; Silldorff & Robinson, 2023; Villarroel et al., 2018). Effective evaluation is hampered by an inability of educators to clearly delineate what they are attempting to measure. Lack of clarity among curricular terms can lead not only to confusion among educational researchers but also within educational communities (Johnson & Gallagher, 2021).

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While often used interchangeably in casual discourse, learning outcomes, learning goals, competencies and core concepts represent distinct, yet deeply interconnected, pillars of curriculum design. Misunderstanding or misuse of these terms can lead to misaligned assessments, curricular gaps, and a disconnect between what is taught and what students truly need to learn. This ambiguity in terminology in A&P education and educational research can potentially lead to a lack of differential meaning in educational contexts (Britson et al., 2023; Crowther et al., 2024; Derek Bok Center for Teaching and Learning, 2025; Human Anatomy & Physiology Society, 2020b; 2020c; Hartel & Foegeding, 2006; Johnson & Gallagher, 2021; Nilson, 2015; Tomicek et al., 2024). The incorrect use of terminology may lead to limitations in the understanding of suggestions or recommendations being offered for curriculum development and potentially hinder organizations working towards reform in A&P education. It is therefore important to differentiate between these curricular terms, as understanding their differences and synergistic relationship is crucial for creating robust, transparent, and impactful educational experiences across educational levels.

Distinguishing Among Curricular Terms

Developing any curriculum is based on answering three essential questions. What do learners need to know? Why do learners need to know this? How will learners show what they know? Answers can only be arrived at with the appropriate use of often erroneously interchanged curricular terms: core concepts, learning outcomes, learning goals, and competencies. Being able to differentiate and distinguish between these curricular terms means that one can correctly apply them within the context of educational discussion and curriculum development (Brownell et al., 2014; Burgoon et al., 2019; Cary & Branchaw, 2017; Chen et al., 2023; Connolly et al., 2018; Davis & Autin, 2020; Derek Bok Center for Teaching and Learning, 2025; Human Anatomy & Physiology Society, 2020b; Hartel & Foegeding, 2006; Hull et al., 2017; Michael & McFarland, 2020). For clarity, we offer the following definitions:

- **Core concepts** are singular, independent concepts that, while unique, are found throughout aspects of a specific discipline regardless of the content of the curriculum being covered. They are a continuum from being overtly expressed within a lesson plan to simply being implied within the context of the content being covered.
- **Learning outcomes (or objectives)** are what the learners should be able to do with the information they garnered from the course content.
- **Learning goals** are the instructor's intention for a lesson or collection of lessons within a curriculum.
- **Competencies** are measurements and evaluations of what a learner is able to do with obtained knowledge or skills.

Using these constructs, educators can scaffold content to reflect previous knowledge or build on existing knowledge to dispel incorrect or incomplete understanding of the construct. This prevents misinformation from persisting within the student's knowledge base (Osborne & Pimentel, 2022; Williamson, 2016). Scaffolding can best be represented as shown in Figure 1. As depicted in the figure, core concepts are indirectly incorporated in learning goals and directly applied in all learning outcomes. These terms then blend together, leading to the competencies by which students demonstrate they have mastered the materials or acquired the necessary skills related to the topics. This organization reinforces that core concepts and learning outcomes are "what" the student will learn, the learning goals are "how" the educator will focus their teaching, and the competencies will be the test questions or lab skills that evaluate the learner's progress.

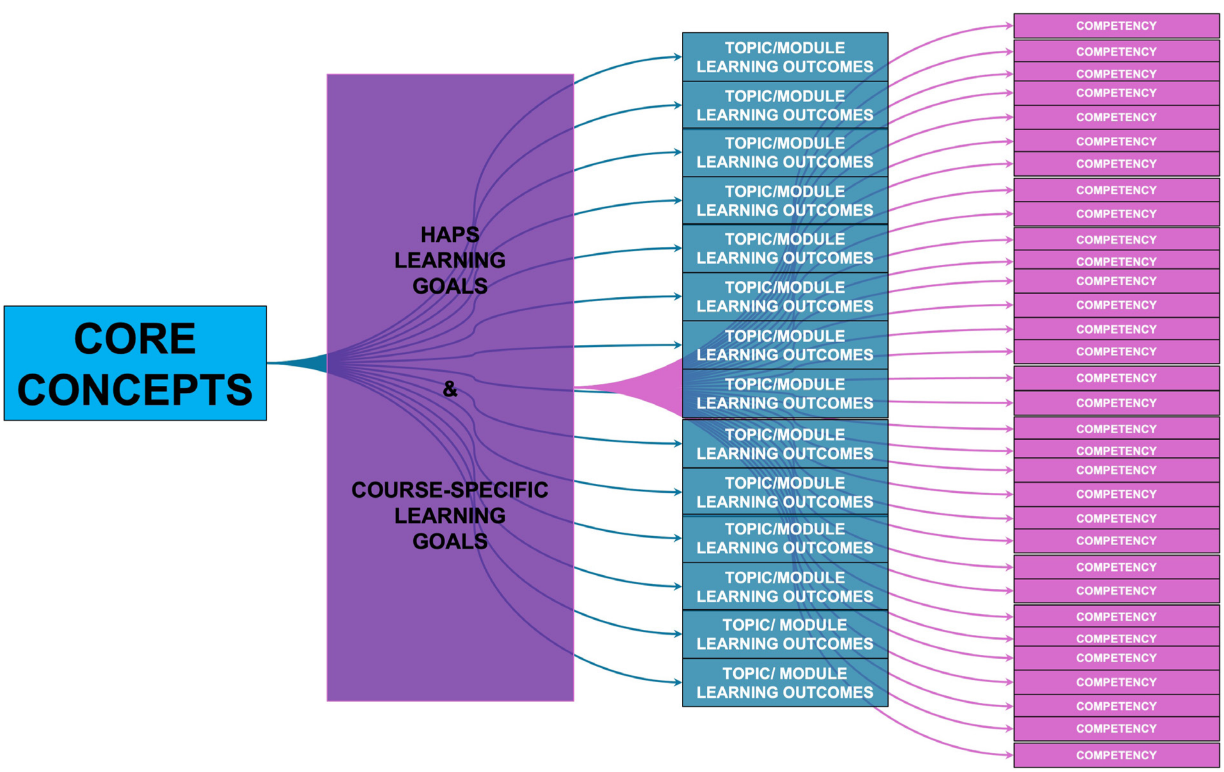

Figure 1. *Mapping the core concepts through the learning goals and into the topic or module-specific learning outcomes that will lead to the various competencies that are ultimately going to be the measures of mastery. Graphic Illustration developed by HAPS C&I Goals and Guidelines Subcommittee.*

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With this scaffolding in mind, one can explore the uniqueness of each term and then illustrate how these curricular terms work in concert to provide a comprehensive framework for teaching and learning.

Core Concepts

The idea of core concepts is not unique to A&P and is seen across a host of disciplines. Most notably for A&P are the recommendations offered in the early 2000's from the Vision and Change proposal for biological education, which emphasized the development of the biology core concepts that have been the cornerstone for biological education (Brownell et al., 2014; National Science Foundation, 2012). Subsequently, core concepts have been proposed in physiology, neurobiology and other related scientific disciplines (Brownell et al., 2014; Chen et al., 2023; Michael et al., 2017; Michael & McFarland, 2011). For many A&P educators, this emphasis for content came from the ideas that the American Physiological Society (APS) developed as a set of core concepts (Michael et al., 2009; 2017; Michael & McFarland, 2011), many of which arose from the primary ideas of general models and "big picture" ideas first put forth by Modell (2000), that became the foundation for identifying content to be covered.

Core concepts are meant to constitute the fundamental principles that frame how to think about a discipline, whether as a novice or an expert. They are ideas that are central to all aspects of the discipline and provide a framework for connection between topics that aids organization and understanding for both students and educators. Within A&P education and instruction, it is important to recognize that regardless of how they are presented, core concepts are not goals, nor are they guidelines for learning (Michael & McFarland, 2023). Core concepts are, rather, distinct and unique entities that span the discipline's content while retaining their uniqueness.

For A&P, these core concepts can include, but are not limited to:

- Structure and function: defining the fundamental interrelationship between any structure and its function.
- Structural organization: defining the unique nomenclature used to describe structure and function by regional and hierarchical organization within the human body.
- Homeostasis: defining the ability for the body to use feedback mechanisms to allow for optimal performance and/or survival through cell-to-cell communication and adaptation responses to stresses.
- Growth and changes over time: defining the developmental and maturation changes or adaptations that occur across one's lifespan (from fetal development through old age).

Core concepts do not, by themselves, specify what is learned or how an instructor will know that a student has learned the material. Instead, they provide a framework upon which all disciplinary knowledge is built. They answer the central question "what are the indispensable ideas that must be understood to be literate in the field?" As answers to this central question, core concepts provide rationale for developing the topic-dependent learning outcomes contained within the course.

Learning Outcomes

If core concepts are the foundation of the building, the learning outcomes (LOs) are the building's bricks and mortar. LOs operationalize core concepts, as the core concepts span topics and become embedded within multiple learning outcomes. They break down large, abstract ideas into smaller, teachable, and assessable chunks. LOs become the specific, measurable, and observable statements that describe what a student should know, understand, or be able to do upon the completion of a specific learning activity such as a lecture, a lab, or a module (Britson et al., 2023; Burgoon et al., 2019; Derek Bok Center for Teaching and Learning, 2025; Hartel & Foegeding, 2006; Lyons et al. n.d.; National Science Foundation, 2012). They are written from the student's perspective and utilize precise action verbs, often guided by frameworks like Bloom's Taxonomy (Main, 2021).

LOs have become the fundamental unit of instructional design and assessment, often at the expense of the learning goals and long-term retention or transference of knowledge. However, they do make learning targets transparent for students and provide a metric for the instructor when focusing content to an aligned assessment. An LO is a clear, concise statement that describes what a learner will know, be able to do, or construct ideas about upon completion of a lesson or learning activity. LOs are focused on the product of learning and are defined by their ability to allow for assessment, but they are not the guide for how to teach the lesson or the assessment metric used to measure content mastery.

While there are a variety of specific LOs available in any of the multitude of A&P textbooks or through various associations and organizations (i.e., Human Anatomy and Physiology Society, American Physiological Society, American Association for Anatomy, American Association of Clinical Anatomists), they all share a common theme for A&P education and instruction (Britson et al., 2023; Brownell et al., 2014; Human Anatomy & Physiology Society, 2020c; Smith et al., 2016; Tomicek et al., 2024). They all provide instructors, authors, or test-writers with the means to create a single, unambiguous exam question or assessment device for a skill that has been acquired. Overall, LOs can be thought of as both instructor-free and instruction-dependent, i.e., they are not linked to how the lesson is taught or what the

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instructor is doing within the lesson. They are factual or skill-based statements about the knowledge that students should have learned or skills they should have acquired related to a specific topic.

In A&P education, the Human Anatomy & Physiology Society (2020c) has provided an extensive, but not exhaustive, list of LOs, that include examples for the first semester of an A&P curriculum such as:

- Identify and define the anatomic planes in which a body might be viewed.
- List the organ systems of the human body and their major components.
- Define homeostasis.
- Compare and contrast positive and negative feedback in terms of the relationship between stimulus and response and describe examples of each.
- List the following types of bonds in order by relative strength: nonpolar covalent, polar covalent, ionic, and hydrogen bonds.
- Define the term organic molecule.
- Describe the structure of the plasma (cell) membrane, including its composition and arrangement of lipids, proteins, and carbohydrates.
- Compare and contrast osmolarity and tonicity of solutions.
- Explain the role of ion concentration gradients and membrane permeability to ions in establishing a membrane potential.
- Classify different types of epithelial tissues based on structural characteristics.
- Describe tissue repair following an injury.
- Identify and describe the tissue type making up the epidermis.
- Describe the functions of the dermis, including the specific function of each dermal layer.
- Explain how the integumentary system maintains homeostasis with respect to thermoregulation and water conservation.
- List and describe the cellular and extracellular components of bone tissue.
- Identify and describe the structural components of a long bone and explain their functions.
- Explain the hormonal regulation of skeletal growth.

Notice the specificity with which each LO targets a discrete piece of knowledge or skill. They operationalize core concepts to ensure that the teaching of these concepts moves beyond simple coverage of information to potentially demonstrable mastery. This is where confusion can occur, because even though they are outcomes, they are not the same as learning goals (Davis & Pinedo, 2021; Derek Bok Center for Teaching and Learning, 2025; Graff, 2011; Hartel & Foegeding, 2006; Whetten, 2007).

Learning Goals

Learning outcomes and learning goals may be interchanged frequently, yet we argue that they are distinct concepts with important roles in curricular design and development. While both learning goals and learning outcomes will have demonstrable, assessable factors to them, the scope and the focus of these factors are drastically different. Learning outcomes focus on a specific detail within the content or skill that was developed that tends to be limited in scope to a single lesson or short sequence of lectures on a specific topic. This is opposed to learning goals that might deal with a similar content or skill but are broader in scope and tend to span the entire course and multiple concepts.

Additionally, a common misconception is the intended focus for the learning goals versus the LOs. The scope of the learning goals is not to serve the student directly but, rather, to serve the instructor (Derek Bok Center for Teaching and Learning, 2025; Hartel & Foegeding, 2006). This means that LOs (or learning objectives) are student-focused and instructor-independent (i.e., what the student is expected to be able to do without stipulation of how they are to learn), while learning goals are instruction-focused and student-independent (i.e., what the instructor will do because of the student-focused learning outcomes) (Davis & Autin, 2020; Derek Bok Center for Teaching and Learning, 2025; Hartel & Foegeding, 2006; Whetten, 2007). Learning goals are competency-based statements that are meant to justify how instruction and assessment prepare students to apply what is being taught, regardless of the methods employed (e.g., backwards design, blueprinting, authentic learning, active learning, Socratic-didactic instruction) (Brashinger, 2017; Davis & Autin, 2020; Derek Bok Center for Teaching and Learning, 2025; Finn et al., 2019; Hartel & Foegeding, 2006; Nilson, 2015; Villarroel et al., 2018; Whetten, 2007; White & Maguire, 2021).

The LOs are meant to define what a student is learning and detail what they can do with their knowledge, while the learning goals define how the course is developed and why instruction is being structured as it is structured. The nature of learning goals is to be holistic, transferable, and action-oriented for instruction but not learning. They will not only encompass the core concepts and learning outcomes but justify the "why" of education—the ultimate goal of preparing effective life-long learners and professionals (Derek Bok Center for Teaching and Learning, 2025; Hartel & Foegeding, 2006). Learning goals unify learning within the course and provide a means to outline curriculum development (Human Anatomy & Physiology Society, 2020a; 2020b). At the same time, because of the content-focused

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educational atmosphere, some instructors rely upon the core concepts for this role rather than developing their own learning goals for a course (Behrendt et al., 2020; Cole & Doherty, 2025; Hull et al., 2017; Michael et al., 2009; 2017; Michael & McFarland, 2023). This propagates the idea that core concepts are guidelines for learning instead of being the core ideas that factual information within the discipline is based upon (Cole & Doherty, 2025; Michael & McFarland, 2023).

For A&P education, the Human Anatomy & Physiology Society (2020b) has offered learning goals to help with curriculum development that include:

- Use appropriate terminology to discuss anatomy and/or physiology.
- Identify anatomical structures and describe the complex interrelationships between structure and function.
- Explain how body systems work together to maintain homeostasis.
- Explain how variability in the human population produces ranges of values considered to be expected and healthy for any given body parameter.
- Propose evidence-based hypotheses to explain physiological responses or the functions of anatomical structures.
- Apply knowledge of anatomy and physiology to real-world situations.

Competencies

Competencies are not simply advanced skills; they represent the integration of knowledge with application (Abrahams et al., 2022; Alagbonsi et al., 2025; Crowther et al., 2024; Hartel & Foegeding, 2006; White & Maguire, 2021). A competency is a dynamic combination of core concept knowledge with the skills honed through learning outcomes, as realized through the objective of learning that is expected of the student. They are proof of learning and an indication of mastery of understanding. While they might represent knowledge, e.g., factual recall, they blend the learning goals for the A&P course with the LOs of the topic being covered at the time of assessment. Despite the common approach to view competency as the ability to pass a test or show knowledge about some distinct A&P content area based solely on factual recall, this would be an unfair generalization and oversimplification of the term. While one can use a lecture or laboratory test to assess content knowledge through factual recall, this does not indicate mastery, because competencies are not solely assessed with a single test or purely by the identification of structures in a laboratory practical exam.

Competencies require students to mobilize knowledge across various contexts and potentially different modalities of expression, demonstrating understanding and not simply rote recall (Crowther et al., 2024; Derek Bok Center for Teaching and Learning, 2025; Hartel & Foegeding, 2006; Nilson, 2015; Silldorff & Robinson, 2023). They are the demonstrated ability to apply knowledge, skills, and professional behaviors that are expected of the student within a given discipline. This is where an individual applies what has been learned to solve complex problems, perform tasks effectively, and adapt information to new situations or real-world contexts.

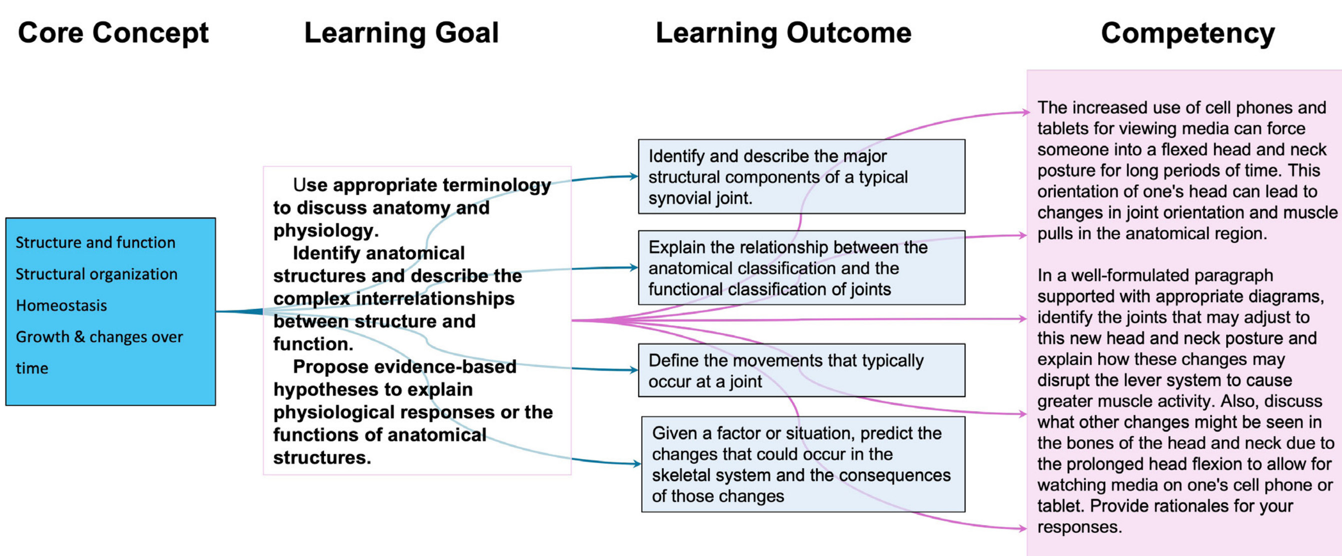

Figure 2. *The interrelationship of core concepts, learning goals, learning outcomes and competency that can be demonstrated with the development of a practical application question. Graphic Illustration developed by HAPS C&I Goals and Guidelines Subcommittee.*

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Figure 2, illustrates how core concepts, learning goals, and learning outcomes intertwine to form a competency-based assessment. The same assessment structure can be used at any educational level; only the expectations shift to reflect the course's learning goals and the depth of application required of the students. To demonstrate competency, learners must synthesize ideas based on integrating the indicated core concepts, learning goals and learning outcomes so that an instructor can employ the check of competency either formatively (i.e., group discussion) or in summative assessment (i.e., short-answer or essay response question). In this way, each competency becomes the holistic and performance-based measure meant to answer the question: "How can a learner use their accumulated knowledge and skills?" Competencies therefore provide the metric of assessment and the item in the portfolio that the instructor can use to justify the curriculum.

For A&P education, any competency must align with the aforementioned learning goal of applying the scientific method to demonstrate scientific reasoning and literacy for the content being taught (Crowther et al., 2024; Osborne & Pimentel, 2022; Silldorff & Robinson, 2023). This requires students to inductively or deductively reason in order to synthesize ideas across multiple learning outcomes and apply them to solve a problem or execute a procedure. At the same time, this competency should also reflect the essence of the course within the totality of the curriculum for the learner, in which A&P often serves as a prerequisite for clinical programs or advanced study in a variety of health science fields (Behrendt et al., 2020; Brown et al., 2017; Cheung et al., 2021; Connolly et al., 2018; Crowther et al., 2024; Tripp et al., 2024). This means that competencies should not only assess knowledge and scientific reasoning but must also bridge the gap between academic knowledge and professional practice that prepares students for where their knowledge will ultimately take them.

Conclusion

In A&P education, precision is paramount—not just in our scientific language, but in our pedagogical language as well. By clearly differentiating among core concepts, learning outcomes, learning goals, and competencies, we move beyond a content-coverage model to a more intentional and effective framework. This framework encourages us to teach the "big ideas" (core concepts), build specific knowledge blocks (learning outcomes), and develop curriculum with the objective (learning goal) of how students will show their ability to use that knowledge in meaningful ways (competencies).

Adopting this deliberate, hierarchical approach provides clarity for learners, focuses instructional design for educators, and ultimately produces graduates who do not just recall facts, but who can think critically and apply their profound understanding of the human body to the complex challenges that lie ahead. Distinguishing among learning goals, competencies, learning outcomes, and core concepts is not an exercise in academic pedantry. Rather, it is a critical step toward intentional and transparent curriculum design. Educators who can deftly navigate these layers can construct learning experiences that are both rigorous and relevant. They can clearly communicate their goals to learners, design aligned assessments, and ultimately provide evidence that their teaching is not just covering material, but is genuinely building capable, knowledgeable, and adaptive thinkers. By respecting the unique role of each curricular element, we move closer to achieving the highest goal of education: empowering learners to effectively transform knowledge into meaningful action.

About the Authors

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PERSPECTIVES ON TEACHING

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Exploring Student Perspectives on Transactional Distance in a Blended Undergraduate Anatomy Course

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Abstract

The rise of online learning, amplified by COVID-19, offers flexibility in teaching approaches, but also challenges engagement. Transactional distance theory highlights one such challenge – the perceived gap between the instructor and the students in online settings. This quality assurance study explored factors affecting transactional distance in a blended undergraduate anatomy course with asynchronous online lectures and synchronous in-person laboratories. Specifically, it investigated a convenience sample of student perspectives on the role of green screen technology in promoting teaching presence and its perceived impact on transactional distance. Anonymous written feedback from the evaluations in a large course (n = 803) was analyzed using deductive thematic analysis. The analysis centered upon the three pillars of transactional distance – instructional dialogue, program structure, and learner autonomy – and was organized into six related themes: improving dialogue, impeding dialogue, enhancing structure, undermining structure, increasing learner autonomy, and decreasing learner autonomy. Overall, green screen technology and instructor enthusiasm were perceived to enhance instructional dialogue and reduce transactional distance. Conversely, elements related to the volume of content and how it was organized were seen to increase transactional distance. Thus, a comprehensive approach that addresses each of the three pillars is essential for effectively managing transactional distance in blended learning. Strategies such as increasing instructor presence via green screen, conveying enthusiasm and relatability, providing structured resources, and carefully segmenting content may effectively lower perceived transactional distance and boost student engagement. The findings are integrated with multimedia learning principles and cognitive load theory. https://doi.org/10.21692/haps.2026.009

Key words: anatomy, transactional distance, teaching presence, green screen, thematic analysis

Introduction

Online learning has been used as a curriculum delivery strategy across the world in many different education systems. It necessitates the use of online resources to aid students' learning, such as instructional videos for introducing new content and digital worksheets to practice the application of knowledge. Common platforms used to facilitate online environments include learning management systems like Google Classroom (Alphabet Inc.; Mountain View, CA), Brightspace (D2L; Kitchener, Canada), Blackboard (Reston, VA), Canvas (Salt Lake City, UT), and Sakai (Apereo Foundation; Princeton, NJ). While online learning has long been prevalent, it has grown substantially in popularity since the onset of the coronavirus disease 2019 (COVID-19) pandemic (Heo et al., 2021). The emergence of COVID-19 as a global pandemic forced a rapid but massive shift in learning environments for students. Teaching transitioned from being facilitated largely in-person with supplementation from online resources to, in most cases, entirely online environments with either synchronous components, asynchronous components, or a combination of both through blended approaches. While sudden, this change allowed for university students to have more flexibility in curating their degrees and enabled them to learn at their own pace (Condon, 2013), making their educational experience more individualized and varied (Poláková & Klímová, 2021). For example, a student may

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choose to complete the allotted learning material for one week of the course in just one day, or to spread out over the week, depending on their schedule and commitments. This individualized and flexible learning allows for more personal goal setting, self-monitoring, and self-evaluation, which are key elements of effective learning (Schunk & Greene, 2017). However, when implemented incorrectly, online learning has the potential to be disengaging, impersonal, and costly (Condon, 2013).

Online learning, if not adequately supported by course structure, can be demotivating for students, which was especially clear in many COVID-19 pandemic-era learning environments and many university-level courses in which content was primarily delivered asynchronously (Ferraro et al., 2020). While asynchronous content provides the advantage of allowing for students to set their own learning pace and timing, it forces students to exercise more ownership and control over all aspects of their education, which requires tremendous motivation, initiative, and organization (Poláková & Klímová, 2021). Since students learning online are inherently required to be more independent from their instructors, this separation can, at times, hinder the relationship between the instructor and their students, which is only exacerbated if a course lacks adequate opportunities for face-to-face communication (Oraif & Elyas, 2021). Further, this may push students to be "lazy in [their] learning process[es] because [they are] not under the domination of the teacher and the school administration" (Oraif & Elyas, 2021).

One idea that may help explain this concept is transactional distance (Moore, 1993). Explained simply, transactional distance refers to the distance that a student feels from their instructor during online instruction (Moore, 1993). The theory describes the real or perceived gap that exists between the teacher and the student, which creates opportunities for misunderstanding (Roach & Attardi, 2022). For example, while seated in an in-person classroom setting, a student is far less likely to openly use their phone in front of the instructor than if they were instead attending a synchronous online lecture using videoconferencing software in which the student's camera and microphone were turned off. According to Moore's theory, such a phenomenon could be explained by the increased distance that a student feels from their instructor when they are separated by an online barrier (Moore, 1993). To extend that example, the perceived distance would be even greater if the instructor were also to turn off their own camera, similar to what is experienced in an asynchronous learning environment wherein the instructor offers pre-recorded lectures with audio only voice-over. How this distance impacts the learner's cognitive resources must also be considered in the design and delivery of a course. Cognitive Load Theory posits that optimal learning occurs when extraneous distractors are reduced to optimize the student's cognitive resources. So, improving focus and engagement by reducing transactional distance can contribute to a more effective instructional environment (Wold, 2011; Roach & Attardi, 2022).

Moore believed that transactional distance predicates itself on three variables: instructional dialogue, program structure, and student autonomy (Moore, 1993; Roach & Attardi, 2022). Instructional dialogue refers to any communication occurring between the instructor and the student. This can also be interpreted more generally as how much the instructor is present in the learning process, such as through in-person office hours or being readily available for and responsive to questions. Instructional dialogue has an inverse relationship with transactional distance, in that as instructional dialogue increases, transactional distance decreases, which is beneficial for student engagement and learning (Huang et al., 2016). Program structure refers to how responsive the course or broader program is to the students' needs (Huang et al., 2016). Literature about transactional distance is somewhat conflicted on the evidence of a direct relationship between program structure and transactional distance (see Benson & Samarawickrema, 2009; Kearsley & Lynch, 1996; Moore, 1991, 1993; Saba & Shearer, 1994). However, the general consensus is that the more highly structured a program is, the less instructional dialogue is required (Moore, 2013), which can lead to less communication from instructors and increased transactional distance (Huang et al., 2016). Finally, student autonomy refers to how much freedom students are given to make decisions about their learning, assessment, or other aspects that are typically dictated by the instructor (Huang et al., 2016). Transactional distance increases with student autonomy, as the more that the student must do by themselves, the more independent they are required to become and the more disconnected they may feel from the instructor (Roach & Attardi, 2022). This conflicts with the traditional and often-cited goal of increasing students' opportunities for self-directed learning and independence to promote those non-technical, discipline-independent skills (see Moreira & Araújo Lima, 2024).

Now, the question presents itself: how might an instructor approach the task of reducing transactional distance in an asynchronous online learning environment to create a more valuable learning experience for their students? This has been explored previously, mostly through augmenting the instructional dialogue component of Moore's concept (Onat & Gülseçen, 2023). One such study examined the possible role of a chatbot in reducing transactional distance (Onat & Gülseçen, 2023). Chatbots are computer programs that act as conversational agents, in this case used to address common inquiries that students may have about class material (Onat & Gülseçen, 2023). The study focused on a first-year university cohort in a remote-learning context and found that the chatbot helped to increase instructional dialogue by being readily available to ask questions, assess assignments, and bolster students' motivation and self-efficacy by providing

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timely feedback (Onat & Gülseçen, 2023). This helped to decrease student disengagement from the course and allowed them to perform at a higher level (Onat & Gülseçen, 2023). However, this method of reducing transactional distance may only work in large classroom settings, where it is not possible for the instructor to allot one-on-one time with every student. In smaller courses, it could feel quite dismissive for students to be directed to a chatbot instead of an instructor, and the feeling of dismissal could, in turn, increase transactional distance by negatively impacting teaching presence.

Instructor presence, or teaching presence, is defined as the real or perceived presence of an instructor in a course (King et al., 2023). In online learning, this can be mediated through manipulating various components on the screen of a virtual lesson, such as visual cues. Research has shown that pairing visual cues that direct learner attention to relevant information with instructor presence may improve learning (Johnson et al., 2014). Additionally, from an affective perspective, instructor presence may improve the satisfaction and positivity a learner feels (Polat, 2023), thus tying it into the pillar of instructional dialogue in Moore's transactional distance theory, which refers to the nature of communication between the instructor and students. However, with a lack of a medium for in-person communication, instructional dialogue, and thus, instructor presence, may suffer. Therefore, given the difficulty of cultivating instructional dialogue in an asynchronous online-only course, any attempt at increasing teaching presence within the learning resources themselves should be entertained.

As a quality assurance measure, and to examine the interplay between teaching presence and transactional distance, course and instructor evaluations from a cohort of novice undergraduate students enrolled in the Fall 2023 Systemic Approach to Functional Human Gross Anatomy course (Kinesiology 1060/2222, Health Sciences 2300, and Nursing 1330) at Western University were examined in this study. Content was primarily delivered online and asynchronously but included a weekly one-hour in-person laboratory component to supplement students' learning, thus following a blended online format. Since the laboratory sessions were facilitated exclusively by teaching assistants (TAs), the only contact the instructors had with students was through pre-recorded lecture videos, email, and optional online office hours on Zoom (Zoom Video Communications; San Jose, CA). So, to increase teaching presence, one instructor chose to implement green screen technology to embody the voice-over used in the lecture recordings and to visually demonstrate bodily movements during the musculoskeletal anatomy units. Thus, the focus of this study was to examine this and other factors of the learning environment to see how they influenced transactional distance, particularly in areas where increasing teaching presence was intentional. Anonymous written feedback related to the course was obtained from students through the course evaluation system and analyzed through deductive thematic analysis to explore semantic and latent themes related to teaching presence and transactional distance. While this study was exploratory in nature, it was expected that students would express positive perceptions related to the use of green screen technology and other elements that increased instructor presence (e.g., instructor announcements, office hours, etc.).

Methodology

Participants and Course Description

Undergraduate students were recruited from a mandatory introductory anatomy course (n = 803) within the Faculty of Health Sciences (open to the Kinesiology, Health Studies, and Nursing bachelor's programs) at Western University in Fall 2023. The 12-week course included two weeks on introductory anatomy (terminology, planes of reference, tissues, etc.), two weeks on the nervous system, six weeks on the musculoskeletal system (three weeks on upper limb, two weeks on lower limb, one week on trunk), one week on the cardiovascular system, and one week on the respiratory system. Accordingly, the course was divided into five units: 1) Introduction to Anatomy, 2) Nervous System, 3) Upper Limb, 4) Lower Limb and Trunk, and 5) Cardiorespiratory System. The content was delivered asynchronously through pre-recorded lecture videos by two different instructors. Instructor A created their recorded lectures (Units 1, 2, and 5) with voice-over only, whereas Instructor B superimposed videos of themselves onto their lecture slides using a green screen for the musculoskeletal system units (Units 3 and 4) so that bodily actions could be demonstrated. Typically, students were tasked with watching two to four lecture videos per week for a total of one to three hours of new content. At the end of each unit, students were required to complete an online quiz (15 multiple-choice questions) on the content covered in that unit. The top four out of five quiz scores contributed a total of 20% towards their final grade. Summative evaluations included a 70 multiple choice question midterm examination on content covered in Units 1 to 3 (20% of the final grade) and a 70 multiple choice question cumulative final examination at the end of the term that was more heavily weighted towards Units 4 and 5 (30% of the final grade). An additional component of the final grade came from regular contributions to PeerWise (Aukland, New Zealand), a program through which students were tasked with creating ten of their own multiple-choice questions to contribute to a class-wide pool of practice questions and attempting 20 of their peers' questions (answer accuracy was not graded). Students were awarded 0.2% for every question they created and answered, up to a maximum of 6% toward their final grade.

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The lecture component was supplemented by one hour per week of self-directed in-person laboratory time supervised by TAs. For these, students would complete instructor-generated worksheets in groups of six, which had them apply the anatomy they had learned in the lecture videos using plastic anatomical models, digital anatomy modelling software (Visible Body Suite; Framingham, MA), surface anatomy palpation, peer-to-peer demonstrations of actions, drawing exercises, clinical application scenarios, and other elements like completing charts and fill-in-the-blanks. The TAs would guide the students' learning and answer any questions on the worksheet activities throughout the first 45 minutes of the session, then the final 15 minutes were dedicated to the completion of an ungraded group laboratory assignment that included one to three application questions addressing a scenario related to the anatomy covered in that week's lectures. Students were awarded with 3% toward their final grade for their attendance and completion of the laboratory assignment in eight out of the 11 laboratory sessions for a total of 24% toward their final grade, meaning they were permitted to miss up to three laboratory sessions without reason or academic penalty. Because of the size of the course, there were 28 laboratory sections that ran throughout the week, which were too numerous for an instructor to be consistently involved in the laboratory component. So, in addition to the laboratory component, students were given the option to seek extra assistance with course material during a weekly online office hour with a course instructor and/or a weekly in-person office hour with a TA in the laboratory. Outside of these times, students also had the option to meet with any member of the teaching team, online or in person, by appointment.

Towards the end of the course, the students were given the option to submit anonymous feedback on the course in the form of Western University's online course evaluation system, Student Questionnaires on Courses and Teaching (SQCTs). There was no academic penalty for choosing not to complete the SQCTs. The anonymous SQCTs associated with Instructor B were accessed for this study, which was considered by Western University's Research Ethics Board to be a quality assurance endeavor that was exempt from oversight. Due to the nature of this exemption, access to Instructor A's course evaluations was not possible, resulting in a quasi-experimental design. Further, since there are no formal teaching assistant evaluations at Western University, obtaining specific feedback on elements of the laboratory sections was not possible.

Data Analysis

The participants' written responses to the "Supplementary Comments for the Instructor" and "Supplementary Comments on the Course" prompts of Instructor B's SQCTs (the only written components of the SQCT form) were analyzed by a single member of the research team (SS) using a deductive approach to thematic analysis examining the concept of transactional distance. The other sections of the questionnaire were comprised of Likert-type prompts for quantitative evaluation of course elements that were not relevant to the research question, nor the qualitative research design used herein, and were, therefore, not examined in this study. The deductive thematic analysis was a non-linear process involving six main steps; 1) familiarization with the data through repeated readings, 2) creation of preliminary codes linking certain aspects of the data with each other, supported by excerpts that illustrated each code, 3) collation and grouping of codes to generate preliminary themes, 4) naming of themes, 5) revisiting the arrangement of themes and codes to ensure comprehensiveness and appropriateness for the research aim, 6) generating a final report of the analysis (Braun & Clarke, 2006). Since this study was designed to be a quality assurance measure and exploratory in nature, the themes were not limited to comments specifically related to green screen video supplementation but focused on factors that could contribute to transactional distance more broadly. These themes were formulated via a mind-mapping strategy, which allowed for visualization of how each code fit into the corresponding theme. Several mind maps were generated as new decisions were made to revise or dissolve certain themes according to the best fit of the data. This was done in consultation with the principal investigator (SM) and other contributors who were not part of the research team but had experience in thematic analysis (see the Acknowledgments section) to ensure the interpretations and arrangement of themes were appropriate for the research aim.

All coding was conducted by the first author (SS), but regular discussions were held with the senior author (SM) to refine the codes and subsequent themes. The first author took the Winter 2024 version of the course for Health Studies undergraduate students, which followed the same format as the Fall 2023 course but was taught exclusively by Instructor B and included overlaid instructor video using green screen in *all* pre-recorded lectures (not just the musculoskeletal anatomy units). As a student, the first author had a positive experience with the green screen technology and Instructor B's teaching, which encouraged them to get involved in research and may have had some influence on their interpretation of the course feedback during analysis. The first author remained mindful of their experience as a student throughout the analysis and thought critically about how it may have shaped their interpretation of the data. This awareness was practiced both when annotating the SQCT responses and when coding the responses by engaging in reflexive exercises such as personal reflections on positionality. Positionality and reflexivity were also discussed in the regular meetings between the senior author and first author throughout the analytical process to promote awareness of the lens through which the data were being assessed. This approach was in line with Braun and

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Clarke's most recent description of *reflexive* thematic analysis, which utilizes the researcher as a central instrument for data analysis and acknowledges their inherent subjectivity as a strength of the process (Braun & Clarke, 2019).

Results

Of the 803 students enrolled in the course, 144 (16%) recorded responses to the SQCTs. This included responses from 30 of 199 (15%) Health Sciences students, 89 of 442 (20%) Kinesiology students, and 25 of 162 (15%) Nursing students. The deductive approach to thematic analysis used to analyze these data resulted in six main themes that were organized according to the three pillars of transactional distance (Moore, 1993) as follows: 1) improving dialogue, 2) impeding dialogue, 3) enhancing structure, 4) undermining structure, 5) increasing learner autonomy, and 6) decreasing learner autonomy. These themes are discussed in more detail below with supporting quotations from the SQCTs.

Improving Dialogue

This theme described feedback related to factors that contributed positively to the instructors' teaching presence in the course. Students felt that the green screen used by Instructor B was a vital aspect of this, reporting that it gave the course more of an in-person feel: ***"Since the lectures are taught online, I find it useful that the videos include your face on the video. Personally, it helps me feel more engaged in the content as if it was being taught in person…"*** Another advantage that the use of green screen conferred to the students was the ability to see the instructor physically indicate various structures on their own body. This, as explained by one student, led to them to be ***"able to understand the course content easier with having a visual of where in the body muscles, nerves, etc. are located."***

However, despite the more in-person feel that the green screen video provided for students, not all lectures implemented this strategy, and the course was still largely based online, with lectures being disseminated in an asynchronous online format. In this respect, students' views were relatively split. While some believed that the online lectures were engaging, others believed the opposite (this is discussed further in the next section). Those who did find the lectures engaging attributed it to Instructor B and how they structured the learning resources, rather than the influence of green screen video, itself: ***"[the instructor's] lectures are expertly put together. They are by far the best online lectures I have had for any course…I found [their] lectures more engaging and effective compared to [Instructor A's] lectures."***

Similarly, many also felt that Instructor B's attitude and enthusiasm contributed to their learning, which reportedly motivated them to want to learn anatomy: ***"Great teacher with lots of enthusiasm. I felt excited to learn the material and this has been my favorite class I have taken so far in my undergrad."*** They cited their use of puns and jokes as having helped them to stay engaged during lessons: ***"I really enjoy the jokes and subtle memory tricks you teach us during the lectures. They never cease to keep me engaged!"***. Further, they reported feeling that this enthusiastic attitude seemed to give the instructor a ***"presence in [their] lectures [that other instructors] lacked [and] I feel is beneficial to the learning environment."***

Impeding Dialogue

This theme captured comments that dealt with factors that impeded instructor presence in the course or weakened the instructor-student relationship. Revisiting student's preference for green screen, they indicated feelings that while the videos enhanced by green screen technology aided their learning and gave an ***"in-person feel"*** to the course, the consensus remained that the course should not be offered online and should instead be delivered entirely in person. The primary reasons that were cited for this were that the online format was not appropriate for the volume of content that the course contained and that the course lacked opportunities for engagement, thereby hindering the students' attention. For example, one student described their feelings as follows: ***"I think that the only thing I would say about this course was that I wish it was in-person – doing a course like anatomy online is quite tough because it's easier to learn content when I'm physically being taught in a class room or lecture hall."***

Other components of the online format and lecture delivery were also reported as being related to engagement or a lack thereof. For instance, many students felt that the lectures were too long and, therefore, hard to follow along with; however, other opinions contradicted that idea. Students who cited a sense of engagement with the lectures typically attributed those feelings to Instructor B and their teaching style. Conversely, those who felt disengagement from the lectures cited more technical aspects such as the duration of the lectures causing their focus to fade away from what the instructor was attempting to communicate to them: ***"Overall it was a good course but the one thing that could be improved is the time length of each lecture. The lectures are really detailed, so it makes it hard to focus on what actually needs to be learned."***

Another dialogue-related issue commonly indicated by students was that Instructor B often gave too much detail on the content in the lectures, without clarifying which information was testable. This led to feelings of confusion and being lost: ***"One thing I would have hoped for, is more clarification on what material was going to be testable. I understand that you cannot spell out all of the quiz and exam material, but as first years, some of us felt very lost in what material we should be focusing on."***

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Enhancing Structure

This theme included factors that the students felt improved the structure of the course. This ranged from the quality of the course components to the helpfulness of the resources provided. Students felt that course was engaging, despite the concerns raised about the detrimental impact of the course being taught online. One student even described the course as ***"very engaging and fulfilling."*** Delving into specifics, another student attributed their like of the course structure to the assessment variety: ***"Great use of class time and amazing assessment variety for grading."***

Additionally, the resources provided by Instructor B also seemed to have a significant positive impact on the students' learning experiences. Particularly, summary charts provided for each musculoskeletal lecture that summarized the important information about each muscle (e.g., attachments, actions, and innervations) covered in that lecture was seen as valuable by most students, who reported that they ***"use them a lot,"*** because they made it ***"easier to study."*** Another resource that was mentioned was the Visible Body Suite software, which allowed students to look at various anatomical landmarks they were learning about on the human body. This software seemingly helped the students to grasp new concepts: ***"It is a great course and might seem overwhelming at the beginning, but the videos and the new [Visible Body Suite] app really help to grasp the ideas quickly."***

Undermining Structure

In contrast to the previous theme, this theme included factors related to the course structure that weakened the students' experience. In particular, students felt that the laboratory sessions were the main components that weakened their experience in the course. While there were some students who remarked that the laboratory sessions provided good opportunities to ask their TAs questions to clarify content, an overwhelming majority reported that they spent a large portion of their laboratory time not doing much at all that was conducive to learning. This was aptly described by one student:

"If the labs are going to continue to be run the way they were this year, I don't think they are necessary. I'm not sure if this was only for my lab section, but we spent most of the time waiting to complete the [group laboratory] assignment. I think labs would be significantly more useful if the TAs went over the difficult concepts from the lectures with each lab section as a group instead of leaving the students to work in small groups."

Further, on the topic of the laboratory assignments, another student claimed that they were ***"done with the aid of [the lecture] notes making them very easy."***

Increasing Learner Autonomy

This theme encompassed factors that supported students' independence in the course or, in other words, increased the number of elements that students had control over and were responsible for in the course. The factor that students indicated to have contributed most to this was a mismatch between the amount of content that was covered in the course and the guidance they received. Mainly, students felt that the amount of content that they needed to learn was not appropriate for the amount of time given to learn it. ***"I feel like this should be a 1.0 course,"*** remarked one student, ***"because if we are supposed to be caring for the lives of others [upon graduating and entering a healthcare profession], I feel like this class is just memory based and it's easy to forget since it's so condensed whereas if it was prolonged it would be more beneficial."*** This led to the students feeling that approaching the content was ***"intimidating"*** and keeping up with the demands of the course was ***"intense"*** due to the load put on them.

Building on this, another common sentiment was that the heavy content load of the course caused students to use study approaches that were overly ***"memorization based."*** This was described by one student as making it ***"somewhat impossible to enjoy the process of learning."*** Accordingly, the students felt that the course should be restructured in a way that begins with more foundational concepts and slowly builds toward more complicated and specific details, as opposed to simply ***"throwing all the details about a structure at us all at once."***

Decreasing Learner Autonomy

This theme mainly included suggestions that the students made to lessen their independence, or the perceived burden that they were required to carry on their own in order to be successful in the course. One suggestion was that the course content should be divided in a way that is more conducive to students' learning by making it easier to digest the content. ***"Sometimes I did wish some of the lecture content on muscles could have been split up into smaller sections,"*** a student described, ***"It was a lot to take in all at once and they were taught very quickly."*** This suggestion was joined by claims of feeling ***"overwhelmed"*** by the load the present structure of the content delivery put on them.

Discussion

This quasi-experimental study sought to explore the concept of transactional distance in an undergraduate anatomy course with a combination of asynchronous online lecture delivery and in-person laboratory sessions as a quality assurance measure. A deductive thematic analysis of written course evaluations obtained through Western University's SQCT process was conducted, and the following themes were identified based on the three pillars of transactional distance: 1) improving dialogue, 2) impeding dialogue, 3) enhancing structure, 4) undermining structure, 5) increasing learner autonomy, and 6) decreasing learner autonomy. Overall, students reported that the use of green screen technology to overlay video of the instructor onto

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the lecture slides within the lecture recordings may have helped to alleviate the perceived transactional distance they felt in the course. Based on the students' comments, the authors posit that this may have been achieved through improving instructional dialogue. Further, providing efficient resources was suggested to reduce transactional distance through improving structure, and ensuring a balance between freedom and support for the learners was viewed as beneficial to transactional distance through decreasing learner autonomy. Thus, the findings from this study suggest that manipulating the three pillars of transactional distance by increasing instructor presence (dialogue), being mindful of cognitive load in the design of learning activities (structure), and optimizing the balance between self-directed and didactic learning opportunities (learner autonomy) in a blended course may decrease transactional distance and facilitate stronger learner engagement.

Literature describes transactional distance as the real or metaphorical distance that students feel from their instructors, particularly in online education environments, which can be mediated in part by modulating its three pillars through strategies such as increasing instructor presence. However, as evidenced by the study's findings, there are many factors that contribute to perceived transactional distance in an online or blended educational environment. For example, as much as the elements related to instructional dialogue contributed to the students' perceptions of transactional distance, so did program structure and learner autonomy. This indicates that educators wishing to reduce transactional distance within their courses should opt for a holistic and multifaceted approach, rather than focusing solely on instructor presence. In the context of this study, several of the factors that students perceived to have impacted transactional distance also had implications related to cognitive load, which describes the amount of information a learner's working memory must process at once (Plass et al., 2010). Cognitive Load Theory describes this phenomenon through three types of cognitive load: extrinsic, which describes distractors that increase cognitive load; intrinsic, which describes factors inherent to the difficulty of the task that are out of the learner's control; and germane, which describes the load induced by processing new information – in other words, the load that should be maximized for optimal learning (Wold, 2011). Closely related to this concept, specifically in the context of online learning, are the principles of multimedia learning and the cognitive theory of multimedia learning (CTML; Mayer, 2001). This theory states that the way an instructor manipulates multimedia – which describes the simultaneous presentation of verbal and pictorial information – can impact a student's ability to learn the content (Çeken & Taşkın, 2022). Based on these theories and the results of the present study, the subsequent paragraphs will summarize strategies that students in this study highlighted that may be used by instructors to decrease transactional distance in their online courses through processes that respect the parameters of CTML.

One of the most commonly mentioned aspects of the course delivery in the student feedback in this study was Instructor B's use of green screen technology to overlay the video of themselves onto the lecture recordings. As previously demonstrated, many found this to be incredibly engaging and that it simulated in-person teaching to some degree. This strategy, therefore, increased instructor presence, which is known to contribute to an increased dialogue in online courses, and thus a reduction of transactional distance (Moore, 2013). In addition to its effects on transactional distance, however, this strategy also has implications within CTML because of how the addition of an instructor video overlay can impact the learning resource itself. Specifically, since Instructor B was using the green screen video to demonstrate the locations and actions of structures using their own body, essential information was conveyed both in the lecture slides and in the instructor video. This has implications related to the multimedia principle of spatial contiguity, which states that learning is enhanced when corresponding visual and textual information are closer together, reducing extraneous processing (Mayer, 2001). Extraneous processing is distracting information that depletes cognitive capacity without allowing for learning (Mayer, 2001). The split attention effect, closely related to this and to cognitive load, operates in a comparable way, and minimizing it subsequently reduces the extraneous load placed on the learner's working memory (Kalyuga & Liu, 2015). It is proposed that extraneous load can be managed by the instructor through the removal or modulation of distractors present in a learning task (Sweller et al., 2011). When a learner is watching an online lecture video, for example, where the instructor's image is overlaid onto the lecture slides and, therefore, in close spatial proximity to the lecture content, they do not need to look far to shift their gaze between the information on the lecture slides and the demonstrations being performed by the instructor. The opposite would be true of the same learner attempting to learn from a synchronous in-person or virtual lecture, where their instructor is shown either separate from the lecture slides entirely (e.g., as in an in-person lecture) or displayed on a sidebar of the learner's screen at some distance away from the lecture slide content (e.g., as is common in synchronous lectures on Zoom). However, the inclusion of any kind of instructor video is not always helpful for cognitive load. For instance, according to the image principle of multimedia learning, if the instructor video is merely a 'talking head' conferring verbal information without any new visual content, it may increase extraneous cognitive load by serving as a distraction (Mayer, 2001). However, in the context of anatomy courses like the one explored in this study, overlaying an instructor's image can contribute more information than just the source of the voice heard in the lecture; it can allow for important anatomical landmarks and movements to be demonstrated to the students in tandem with the verbal, textual, and graphical information being

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presented in the lecture slides. This reinforces the spatial contiguity principle and seeks to reduce extraneous load and processing (Mayer, 2001).

A less explored method, yet one that was heavily referred to in the students' feedback in this study, was that of Instructor B's personality, enthusiasm, and teaching style, which they suggested to have improved their learning. This study necessitated its mention due to the outpouring of comments from students expressing that Instructor B's enthusiasm for anatomy was evident and that it left a significant impact on their learning experience. Particularly, Instructor B tended to make subject-related jokes or puns that were appreciated by the students and reportedly increased their engagement. The increase in engagement that this strategy fostered can be seen as having promoted dialogue between the instructor and the students, thus reducing transactional distance. Specifically, the more 'human' elements of instructor personality and enthusiasm emulated the personalization principle, a multimedia learning principle that states that learning may be improved by utilization of an informal, conversational voice as opposed to a formal one (Mayer, 2001). This is suggested to help foster germane processing, as it motivates the learner to want to make sense of the information (Mayer, 2001). Germane processing is the function of processing novel information and adding it to one's reservoir of previous knowledge (Mayer, 2001). In a study that explored the connection between these two variables, researchers found that the usage of an enthusiastic voice caused participants to respond more to questions and leave less spaces blank on tests, which exemplifies an outcome often associated with increased task motivation (Motz et al., 2017). Increasing engagement in this way could also serve to reduce extraneous load by concentrating the focus of the learner on what the instructor is describing, rather than distractors in the environment (Plass et al., 2010). Although the use of an enthusiastic voice may improve engagement (Motz et al., 2017), no direct correlation has been made between use of an enthusiastic voice and improved learning outcomes. On the other hand, a universal way in which emotion, including enthusiasm, is communicated is through non-verbal cues (i.e., body language and gestures; Matsumoto, 2006), and it has been shown that instructors can leverage this to influence students' motivation and engagement (Pekrun & Linnenbrink-Garcia, 2014). Further, non-verbal cues like eye contact, gestures, and facial expressions have been shown to improve students' academic performance (Zeki, 2009). Thus, it is possible, and perhaps likely, that the students in this study noted Instructor B's enthusiasm and personality precisely because of the use of green screen video overlay and the non-verbal communication it allowed. However, more research is required to understand how this phenomenon impacts student learning.

Resource design and content delivery were also major components discussed within the student feedback. Because the amount of content in a topic such as anatomy can be quite voluminous and overwhelming, this was regularly and repeatedly expressed as a barrier to the students' learning. Although, the argument can be made that despite every effort from an instructor to make learning materials concise and easy to understand, some students will still struggle to truly grasp the content because of a perceived overload of information and subsequent demotivation. Thus, streamlining the communication of information-dense topics remains a primary concern for anatomy instructors to address. Particularly, many students in this course criticized the approach that Instructor B took to divide the content, stating that the lecture content should have been divided into smaller, more easily digestible subtopics. This sentiment from the students echoed a commonly used learning strategy called chunking. Chunking involves breaking down large volumes of novel information into smaller, digestible pieces that "provide the learner with the opportunity to revisit smaller units of information" (Humphries & Clark, 2021). In the present study, the volume of content and the length of Instructor B's lectures exacerbated the issue of learner autonomy by requiring the students to be more independent and perform their own chunking while managing and scheduling their asynchronous study time. This was an especially burdensome design for these students, as the majority were novice learners who had not yet developed independent learning skills. Preemptive chunking performed by an instructor can decrease the students' need to manage and divide the content on their own, creating smaller segments of content that are more conducive to their learning. So, chunking can be used to modify course delivery in a way that makes studying more manageable and flexible for students, potentially leading to a decrease in transactional distance (Humphries & Clark, 2021). Further, optimizing program structure in this way can help to reduce transactional distance by providing students with a balanced ownership over their learning without overwhelming them. From a cognitive perspective, chunking reduces the difficulty of the task by breaking it up into more limited and accessible bites of information, thereby reducing the intrinsic load on the working memory at a time (Humphries & Clark, 2021, Plass et al., 2010). Intrinsic load refers to the load that is associated with the difficulty of the task itself, which is modulated by factors largely outside of the instructor's or learner's control, such as the prior knowledge that a learner may have before attempting the learning task (Sweller et. al, 2011). Chunking can allow students to better see and make meaningful connections between new concepts and their existing knowledge since they are able to focus and spend more cognitive energy on discrete units of information (Humphries & Clark, 2021). Although described similarly in CTML, this strategy is referred to as the principle of segmenting, which attributes its benefits to the management

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of essential processing – the act of arranging and processing specific aspects of novel information in the working memory (Mayer, 2001). Ultimately, however, while the students' comments emphasized instructor-mediated chunking as a desirable strategy that would allow them to process novel information at their own pace, doing so would still not completely address learner autonomy, as students would still be learning in an asynchronous environment where they are free to independently schedule their studying.

Limitations

While this study was exploratory in nature and was conducted as a quality assurance endeavor, the method of data collection was not ideal for optimal rigor. More detail and nuance in the students' responses would likely have been achieved by conducting focus groups or interviews designed to assess the students' perceptions of specific elements of the course more deeply. Additionally, the SQCTs were an optional and unrewarded course evaluation process conducted by Western University, so students did not have any course-specific incentive to respond to them. This resulted in a small percentage of students who took the time to respond and likely resulted in some selection bias toward a group of students who were more invested in the course. This limits the power of the study's findings, as they may not be generalizable to larger and more diverse populations of students. Finally, the course that this study analyzed had two instructors, so some of the feedback received may have been coming from a perspective of comparison rather than isolated evaluation, which could have skewed how responses were presented and subsequently interpreted. Further, since only the SQCTs associated with Instructor B were available for this study, any comments related to transactional distance that existed in Instructor A's SQCTs were not captured. This may have biased the discussion toward elements of Instructor B's specific teaching approach and resources and away from other salient elements of the course.

Conclusion

The concept of transactional distance in any online course is a culmination of its three pillars: dialogue, structure, and autonomy. This metaphorical distance can be managed in many ways while targeting these three pillars. Using a deductive approach to thematic analysis, the present study sought to explore the various factors impacting transactional distance in an undergraduate anatomy course that implemented asynchronous lectures and in-person laboratory sessions in a blended format. Student evaluations of the course highlighted perspectives that indicated different ways in which the three pillars of transactional distance were impacted, and what those effects were on their engagement and ultimate learning. Based on these data, recommendations for how to optimize structure and learner autonomy through chunking (or segmenting) and scaffolding content were uncovered. Additionally, the use of green screen to overlay instructor video onto the lecture slides was perceived to have leveraged instructor dialogue to improve teaching presence and decrease transactional distance by showcasing the instructor's personality and enthusiasm for the content, and it may have decreased extraneous load and extraneous processing requirements on students through the spatial contiguity principle of multimedia learning. While the links between these various concepts have yet to be comprehensively tested, anatomy educators may benefit by implementing these strategies in their online and blended courses to reduce transactional distance and increase learner engagement.

The aspect of online learning that this study sought to explore can offer crucial insights for a diverse range of online and blended learning environments. Targeting transactional distance using the strategies outlined herein can offer a relatively inexpensive way to improve students' engagement and learning in such environments. With the exception of green screen video recording equipment and the existing resources in the course (Visible Body Suite software, plastic models, etc.), there was no financial requirement or additional resources needed to implement the other strategies that reportedly enhanced student learning in this study – they could be done for free. Hence, using basic strategies related to instructor enthusiasm and relatability, managing content volume, chunking and scaffolding information, and maximizing the instructional involvement and effectiveness of the course, TAs could offer a low barrier of entry for those seeking to improve the effectiveness of their teaching in online and blended courses. With this in mind, the least costly strategy of utilizing an enthusiastic teaching style should be explored in more detail for its impact on learning outcomes, especially as it pertains to non-verbal communication, as the qualitative data collected herein suggests that some relationship may exist.

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Peer-Led Simulation-Based Education for the Pathophysiology Curriculum

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Abstract

A key challenge in the pathophysiology curriculum is bridging the gap between theoretical knowledge and practical application. Simulation-based learning, specifically peer-led models, may offer a promising approach to enhance the educational experience for pathophysiology students. Participants in this pilot study were undergraduate students who were enrolled in a pathophysiology course at a single institution who completed a 1-hour peer-led simulation-based workshop. The National League for Nursing's Student Satisfaction and Self-Confidence in Learning Scale (0-5 with higher score representing a more positive response) was administered to evaluate students' perception of the peer-led simulation experience. Analysis of survey responses demonstrated that peer-led simulation was positively received by students with a mean (standard deviation) score for satisfaction with current learning of 4.68 (0.47) and for self-confidence in learning of 4.54 (0.47). High levels of satisfaction and self-confidence with were reported for this method of instruction with >90% of respondents stating "agree" or "strongly agree". Findings of this study suggest that peer-led simulation is an effective strategy to promote student satisfaction and self-confidence with pathophysiology coursework. Future studies should evaluate whether the implementation of peer-led simulation experiences within the pathophysiology curriculum enhances knowledge and academic success. https://doi.org/10.21692/haps.2026.010

Key words: pathophysiology, peer-led learning, simulation

Introduction

Simulation-based education is broadly integrated into curricula in the health sciences as an instructional tool to emulate clinical environments (Elendu et. al., 2024). Specifically, high-fidelity simulation provides enhanced realism and interactivity while in a controlled environment for learners (Meakim et al., 2013). These immersive experiences are intended to bridge the gap from theoretical learning to clinical practice. Learning models featuring high-fidelity simulation, defined by a realistic representation of a healthcare environment using computerized patient simulators, promote a deeper level of analytical reasoning, self-efficacy and motivation (Hanshaw & Dickerson, 2020). In undergraduate nursing education programs, high-fidelity simulation has been demonstrated to enhance knowledge acquisition and improve student performance (Vangone et al., 2024). However, data on the potential to enhance the learning experience in prerequisite courses, such as pathophysiology, are limited. Providing exposure to simulation in the pathophysiology curriculum offers experiential learning opportunities within a realistic clinical environment in order to improve competency-based learning outcomes.

Developing and implementing a simulation-based curriculum for pathophysiology may further benefit from a peer-led instructional model. Specifically, peer-led learning offers academic and social benefits that may promote engagement and improve critical thinking in undergraduate students (Choi et. al., 2021). In a peer-led instructional model, students who have successfully completed the course support one another through efforts of collaborative teaching (Gosser et al., 2001; Svellingen et al., 2021). Peer leaders receive targeted training to gain proficiency with pedagogical approaches intended to foster active student learning (Gosser et al., 2001). Weekly workshops codeveloped by faculty and peer leaders are designed to strengthen communication and teamwork through challenges requiring analytical reasoning and

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problem-solving (Gosser et al., 2001). In nursing education, peer-led simulation has provided instruction capable of enhancing simulation performance and improved knowledge levels (He et al., 2024). However, this approach has not been explored for the pathophysiology curriculum. Employing a structured peer-led teaching model in the pathophysiology curriculum may further enhance undergraduate students' experience of simulation-based learning opportunities.

Undergraduate students may uniquely benefit from simulation-based learning experiences in pathophysiology, because the coursework requires students, often for the first time, to bridge theoretical concepts with practical application. Despite the significance of the course content, constraints in the learning environment, including limited class time and student-to-faculty ratios, may hinder the ability of students to connect academic subject matter with clinical relevance (Satoh et al., 2023). In the absence of opportunities to directly observe course content in the clinical setting, students may struggle to relate their understanding of disease processes to authentic clinical scenarios (Satoh et al., 2023). This method of experiential learning has a positive impact on student engagement, which is widely recognized as a critical factor in academic outcomes (Ghasemi et al., 2020). While studies have independently highlighted the benefits of integrating simulation-based education (Vangone et al., 2024) or peer-led learning in coursework (Cupelli et al., 2025), there is limited information on the impact of combining these two models of teaching and learning in pathophysiology. Given the significant potential for peer-led simulation to enhance the undergraduate academic experience in science coursework, the purpose of this pilot study was to develop, implement, and evaluate a peer-led high-fidelity simulation experience in a pathophysiology course. We hypothesized that peer-led high-fidelity simulation would lead to greater satisfaction with learning and self-confidence in learning.

Methods

This study included undergraduate students enrolled in a pathophysiology course at a single institution. During the 16-week semester, pathophysiology students attended weekly peer-led workshops to meet course requirements. During the 2024-25 academic year, the week 15 workshop was designed to be a 1-hour peer-led workshop in the simulation lab.

A pilot study was conducted to evaluate student experiences of participating in a peer-led high-fidelity simulation during a pathophysiology course. This study was approved by the Dominican University Institutional Review Board, and informed consent was obtained from all participants. The Student Satisfaction and Self-Confidence in Learning Scale (SCLS) from the National League for Nursing (NLN) was used to assess student reactions to the simulation exercise (National League for Nursing, 2026). This validated tool consists of 13 survey items scored on a five-point scale from 1 (strongly disagree) to 5 (strongly agree). Survey items are categorized under two domains with five items related to "Satisfaction with Current Learning" and eight items related to "Self-confidence in Learning". Cronbach's alpha is reported as 0.92 for the SCLS (Franklin et al., 2014). Approval from the NLN was received for use of this survey tool. Two additional survey items were included to assess the transition to nursing coursework: "I am looking forward to upcoming clinical courses after this simulation" and "I am less anxious about starting clinical courses after this simulation".

Simulation Experience

Peer leaders were upper-level nursing students selected based on their prior strong performance in the pathophysiology course. The simulation consisted of five distinct case scenarios covering some of the major conditions studied throughout the semester (liver failure, gastrointestinal bleed, kidney failure, pneumonia and heart failure: Appendix 1). Peer leaders collaborated with faculty to design the cases and were responsible for facilitating the simulation sessions with their small groups. Peer leaders and faculty reviewed debriefing techniques to encourage discussion and reflection post simulation sessions. A set of common questions for debriefing after the simulation experience was provided as a guide.

Peer leaders began simulation sessions with a pre-briefing to establish a safe learning environment where students could freely discuss thoughts and questions without concern for judgement while reviewing the expectations and learning objectives. Students were oriented to the unit and provided with charts for the five patients. Charts included discussion prompts strategically developed to emphasize critical learning objectives for the clinical scenarios. Students were allocated 5-7 minutes for each patient room to correlate information gathered from chart review with the patient's clinical presentation. Guidance and support were provided throughout the simulation by the peer leader.

Patient scenarios encompassed a range of clinical data such as vital sign monitors, telemetry, physical exam findings (e.g., respiration patterns, coughing) and observations of various bodily fluids and drains. Simulation staff used microphones to provide verbal response for several manikins allowing students to elicit additional information on their illness through conversation. Simulation learning goals were focused on directly linking symptom presentation to the underlying disease process in alignment with course outcomes. Given that these were undergraduate students without prior clinical experiences, simulation objectives excluded detailed physical exams and the formulation of complex treatment decisions.

At completion of the simulation, peer leaders conducted structured debriefing sessions and participants were offered the opportunity to complete a voluntary survey to evaluate their response to the workshop (Table 1). Data were analyzed using descriptive statistics to report mean and standard deviation (SD) for each survey item and for each domain of the SCLS (satisfaction and self-confidence). Survey item 13 in the SCLS was not included in the calculations for the overall

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scores as recommended in prior literature given its focus on instructors' responsibility rather than evaluation of satisfaction or self-confidence. This has been demonstrated to improve Cronbach's alpha for the SCLS to 0.94 (Franklin et al., 2014).

Were you nervous for the simulation experience?
Did the simulation content seem familiar?
Did you gain confidence as you progressed through the simulation cases?
Did you identify the key symptoms and the correlation to the underlying pathophysiology of the patient presentations in each case?

Table 1. *Guiding Questions for Debriefing*

Results

Among the 90 undergraduate students enrolled in a 16-week pathophysiology course, 86 (95.6%) participated in the peer-led simulation workshop and completed all survey items. Four students did not agree to participate, and their data were not collected for this study. Study participants were racially diverse with 68 students (79.1%) self-identifying as Latinx or Hispanic, 9 students (10.5%) as Asian, Southeast Asian or Asian American), 3 students (3.5%) as White/European, 3 students (3.5%) as Black or African American and 3 students (3.5%) as bi-racial, not listed, or not indicated. The majority or 72 (84%) of students identified as first-generation college students, and 13 (15%) identified as multi-generational students and 1 (1%) chose not to answer.

The scores for the SCLS items are shown in Table 2. The mean score for the five SCLS survey items assessing satisfaction with peer-led simulation was 4.68 (SD 0.47), with 82 (95%) participants indicating "agreement" or "strong agreement" with all statements related to satisfaction with the simulation-based experience. The mean score for the seven SCLS survey items assessing self-confidence with simulation was 4.54 (SD 0.47), with 77 (90%) participants indicating agreement or strong agreement with all statements related to self-confidence. The highest score on the SCLS was on the statement that teaching materials used in the simulation were motivating and helped me to learn 4.72 (SD 0.45). The mean score regarding the statements that simulation reduced anxiety about beginning clinical coursework was 4.22 (SD 0.91) and addressed anticipation for upcoming clinical courses was 4.66 (SD 0.5) (Table 3).

Satisfaction with Current Learning (summary of 5-items)	Mean (SD)	Strongly Disagree N (%)	Disagree N (%)	Undecided N (%)	Agree N (%)	Strongly Agree N (%)
1. Teaching methods were helpful and effective	4.70 (0.48)	0	0	1 (1.2%)	24 (27.9%)	61 (70.9%)
2. Simulation offered variety of materials and activities to promote learning	4.67 (0.47)	0	0	0	28 (32.6%)	58 (67.4%)
3. Enjoyed how simulation was taught	4.65 (0.59)	0	1 (1.2%)	2 (2.3%)	23 (26.7%)	60 (69.8%)
4. Teaching materials were motivating and helped me to learn	4.72 (0.45)	0	0	0	24 (27.9%)	62 (72.1%)
5. Simulation was taught in a way that was suitable to my learning	4.64 (0.59)	0	1 (1.2%)	2 (2.3%)	24 (27.9%)	59 (68.6%)
Summary of SCLS Satisfaction Score 1-5	4.68 (0.47)	n/a				
Self-Confidence in Learning (summary of 8-itms)		**Strongly Disagree (n)**	**Disagree (n)**	**Undecided (n)**	**Agree (n)**	**Strongly Agree (n)**
6. Confidence in mastering content of simulation	4.35 (0.68)	0	2 (2.3%)	4 (4.7%)	42 (48.8%)	38 (44.1%)
7. Confidence that simulation covered critical course content	4.59 (0.54)	0	0	3 (3.5%)	29 (33.7%)	54 (62.8%)
8. Confidence in developing skills and obtaining required knowledge from this simulation	4.57 (0.52)	0	0	1 (1.2%)	35 (40.7%)	50 (58.1%)
9. Instructors were helpful resource during simulation	4.60 (0.51)	0	0	2 (2.3%)	30 (34.9%)	54 (62.8%)
10. My responsibility to learn what is necessary from simulation activity	4.58 (0.52)	0	0	1 (1.2%)	34 (39.5%)	51 (59.3%)
11. I know how to get help with simulation concepts I don't understand	4.56 (0.52)	0	0	2 (2.3%)	34 (39.5%)	50 (58.1%)
12. I understand how to use activities in simulation to learn critical skills	4.52 (0.57)	0	0	3 (3.5%)	35 (40.7%)	48 (55.8%)
SCLS Summary Score 6-12	4.54 (0.47)	n/a				
13. It is instructors' responsibility to tell me what is needed to learn from this simulation	4.01 (0.10)	2 (2.3%)	5 (5.8%)	16 (18.6%)	30 (34.9%)	33 (38.4%)

Data represent frequency counts (n) and % as indicated

Table 2. *Undergraduate Student Responses to the Student Satisfaction and Self-Confidence in Learning Scale (SCLS)*

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Survey Items	Mean (SD)	Strongly Disagree N (%)	Disagree N (%)	Undecided N (%)	Agree N (%)	Strongly Agree N (%)
14. I am looking forward to upcoming clinical courses after this simulation	4.66 (0.50)	0	0	1 (1.2%)	27 (31.4%)	58 (67.4%)
15. I am less anxious about starting clinical courses after this simulation	4.22 (0.92)	1 (1.2%)	5 (5.8%)	7 (8.1%)	34 (39.5%)	39 (45.3%)

Data represent frequency counts (n) and % as indicated

Table 3. *Assessment of Engagement and Interest in Future Clinical Coursework*

Discussion

This pilot study demonstrated high levels of student satisfaction and self-confidence after a peer-led simulation-based learning experience in pathophysiology coursework. To our knowledge, this represents the first investigation to integrate this experiential learning approach in the pathophysiology curriculum. The results of our study demonstrate feasibility and wide acceptability of this method of content delivery among pathophysiology undergraduate students. Additionally, students reported low levels of anxiety to begin clinical coursework and transition to the nursing curriculum. The focus on student-reported attitudes and well-being as outcomes is an important strength of this study and future work should consider objective learning improvements as a result of the intervention. Findings of this study align with previous efforts highlighting the benefits of simulation-based learning while attempting to address several acknowledged gaps in the literature (Hanshaw & Dickerson, 2020; Vangone et al., 2024). Our study begins the work of uniquely scaffolding simulation starting in the pathophysiology curriculum and introducing novice learners to this method of teaching. This approach is particularly helpful for pathophysiology courses where a deeper understanding of theoretical concepts and their application to clinical practice can be amplified with simulation experiences.

This work builds on and extends the available evidence on peer-led educational experiences. However, research on peer-led or peer-facilitated simulation has been limited in the health sciences to-date. Our work builds on the few small studies that have shown the promising potential for this approach. One small study by researchers Xiaofeng et al. (2024) demonstrated that nursing students in peer-led simulation groups can have similar or improved learning outcomes when compared to faculty-led groups in terms of knowledge gains and performance. Moreover, peer-led simulation has also been demonstrated to improve communication proficiency for the peer leaders (Svellingen et al., 2021).

While it is well-established that simulation can provide a more engaging and authentic approach than traditional teaching methods, barriers in terms of facility cost and faculty time may present barriers to expanding these practices. One way to address this barrier would be to leverage existing simulation facilities for established clinical education programs. Maximizing the potential of peer leaders in implementing simulation-based education may also decrease additional burdens placed on faculty.

Study limitations include the small sample size from a single institution. Findings may not be generalizable to other pathophysiology students. Measurements of satisfaction and self-confidence in this study are subjective and future research should evaluate objective student learning outcomes after the intervention such as knowledge gains and exam performance. This cross-sectional study surveyed students' perceptions of participating in high-fidelity simulation at a single point in time, therefore pre-/post-workshop measures, longer-term academic performance outcomes, and graduation rates should be explored. Future work evaluating longitudinal outcomes are needed to evaluate the impact of exposure to peer-led simulation in the pathophysiology curriculum.

Introducing peer-led simulation in the pathophysiology curriculum is a promising strategy to promote student satisfaction and self-confidence. In this pilot study, peer-led simulation was well-received by undergraduate students and offered a viable means to connect theoretical knowledge with clinical application in pathophysiology coursework.

About the Authors

Jonathan Uebelhor received his DNP from the University of Colorado Denver. He is a nurse practitioner with a background in hematology and currently an assistant professor at Dominican University. He has taught Introduction to Human Pathophysiology for the last 4 years with research interest around student engagement, mentorship and sense of belonging on campus. Anna Gouwens, BSN, is a registered nurse on a neurology and spine specialty unit. She recently graduated from Dominican University with her BSN and was a peer tutor in the simulation research project summarized in this manuscript. Maureen Emlund, MSN, is the Director of Clinical Simulation Education Center at Dominican University. She received her BSN from Lewis University and her MSN from Benedictine University. During her professional career, she added simulation training to her skills with more than eleven years of experience working with faculty and professionals in her nursing practice to develop simulation activities and training. Allyson West, PhD, is the Interim Director of Grant Management at Dominican University. Her scholarly interests include the scholarship of teaching and learning in STEM and health sciences.

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Appendix 1. Case Scenarios for the Peer-Led Workshop Applying Simulation-Based Education in the Pathophysiology Curriculum

Case 1: Liver failure

Case prompt: 48-year-old female with hypertension, depression, alcohol use who was brought in by concerned spouse, notes new onset of confusion and slight yellowing of the skin. Patient has been out of work and drinking heavily the last month, likely worsened by symptoms of depression. Patient noted some Right Upper Quadrant Abdominal pain that started the last 48 hours. Symptoms are not worsened or relieved by eating.

Orders:

o Serum Chemistry

o Albumin

o INR

o Paracentesis

Lab Results:

Lab Test	Patient value
Glucose	104
BUN	23
Creatinine	1.1
INR	3.2
Albumin	0.8
Total Bilirubin	3.5
AST	223
ALT	403
Ammonia	165
Amylase	25
Lipase	45

Paracentesis was performed at bedside and 2.5 liters were removed during procedure from peritoneal cavity

Guiding Questions for Discussion:

o What is going on with Mrs. Connors and the likely cause (big picture)

o Can you explain why the patient is confused, and what lab may represent that?

o Why does she have so many bandages and band aides on, which lab gives insight to this cause?

o Why is her skin slightly yellow, and what lab gives insight to this cause?

o What is the collection of fluid that was in her abdomen called, and what lab also plays a role in the build of fluid outside the vessels?

o Does the patient also have pancreatitis?

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Case 2: Upper gastrointestinal bleed

65-year-old female with a history of arthritis and hypertension who is currently taking ibuprofen and atenolol and awoke this morning feeling weak and tired. Phoned her daughter who was concerned that she looked pale. She had also noted some changes to the color of her stool. She tried walking around the apartment in hopes that she would feel better, but she became progressively tired and mildly short of breath. At this point, her daughter brought her to the Emergency Room. The provider has ordered a stool sample for occult stool, the sample is in the commode, along with lab work. The patient notes that her stomach has been bothering her off and on. Pain described as burning, typically happens several hours after she eats. She thought it would go away, but over the last several months, the pain has worsened.

Orders:

o Occult Stool

o Complete Blood Count

o NPO Diet (Nothing to eat or drink)

o Oxygen per nasal cannula

o Telemetry

o Blood Transfusion

Lab Results

Lab Test	Patient Value
WBC	5.6
Platelets	175
RBC	3.25
Hemoglobin	8
Hematocrit	24
Mean Cell Volume MCV	65
Reticulocyte Count	0.7
Occult Stool	Positive
Blood Type	AB+

Guiding Questions for Discussion:

o What is meant by Occult Stool?

o How do you interpret her lab work?

o What do you make of the color of her stool, can that provide us with any information?

o What do you think her diagnosis is, and what is possible cause (hint: medications)?

o Why do you think she is short of breath?

o What is happening to her blood pressure and her pulse, is that expected?

o Can you feel her radial pulse on her wrist?

o What types of blood can he receive as a transfusion

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Case 3: Kidney Failure	
45-year-old who is a landscaper and has been working extensively this week in the hot sun. She is not always good about bringing anything to drink while on her work sites. She started feeling lightheaded and then fainted this afternoon with temperatures in the upper 90s and no shade. Another member of her team rushed her to the ER for further assistance. The provider has ordered some routine lab-work. Jamie tried to void in a cup but was only able to provide a little urine as she has not voided much at all today.	
Orders: o Urine labs/Specific gravity o Serum Chemistry o Start IV fluids o Telemetry o Monitor Blood pressure	
Lab Results	
Lab Test	Patient Value
Glucose	104
BUN	45
Creatinine	3.7
Potassium	5.5
Albumin	2.9
Total Bilirubin	0.4
Urine Specific Gravity	1.055
Guiding Questions for Discussion: o What is the overall problem with the patient, what is her diagnosis? o Is she in acute renal failure, if so, what is the insult (pre - intra - post) o Why is her blood pressure low? o How do her labs support your diagnosis? o Are we worried about her Potassium level (why or why not)? o Is she having Polyuria, Oliguria or Anuria?	

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Case 4: Pneumonia

57-year-old female with a history of chronic obstructive pulmonary disease and active tobacco use who notes worsening of her usual cough. She always has a productive cough of greenish sputum, but the severity of her cough has worsened the last 2 days. She also notes intermittent fevers. One of her friends was recently diagnosed with Influenza. She does not believe in vaccines and did not obtain an influenza vaccine this year. Her breathing has also worsened. While she always wears oxygen, she is now having trouble ambulating across the room due to excessive fatigue. Her partner called 911 this morning because she was concerned she would not be able to get Patricia into the car.

Orders:

o Sputum Culture

o Complete Blood Count with white blood cell differential

o Oxygen per nasal cannula

o Telemetry

o Chest Xray

o Arterial Blood Gas

o Cefepime (antibiotics) for treatment of pneumonia

o Gown and mask in the room

Lab Results:

Lab Test	Patient Result
WBC	13.75
Neutrophils	9.25
Lymphocytes	2
Monocytes	1
Eosinophils	0.3
Basophils	0.8
RBC	4.7
Hemoglobin	13
Hematocrit	39
Influenza A	Positive
Sputum Culture	Pending
Arterial blood gas pH	7.2
Arterial blood gas CO2	55
Arterial blood gas HCO3	24

Chest X-ray results: Fluid buildup and inflammation in Right Lower Lobe, this is new from previous Chest Xray.

Guiding Questions for Discussion:

o Does her description of symptoms fit more in line with Emphysema or Chronic Bronchitis as her COPD diagnosis?

o How do you interpret her blood gas, is that concerning?

o Does she have tachypnea?

o How do you interpret her lab work; does it make sense?

o What is a huge risk factor for her condition?

o What is taking place now, she has COPD, but what else is happening, and how are they related?

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Case 5: Heart failure

67-year-old man with a history of heart failure, arrhythmias, hypertension, and elevated cholesterol who is a retired teacher and presents to the emergency room after noting worsening swelling of his feet and feeling chest palpitations. He tries to walk one block per day but was unable to do so today due to fatigue. He denies having any shortness of breath. Just notes that his feet have been puffy, and his weight has increased 6 pounds over the last few days. He was recently out of town and ate several meals at a local fast food chain.

Orders:

o Telemetry

o Troponin

o BNP

o Echo

Lab Results:

Lab Test	Patient Value
Troponin	0.1
BNP	575
Fasting Glucose	95

Echocardiogram: Enlarged heart consistent with hypertrophy and left ventricular ejection fraction of 25%

Guiding Questions for Discussion:

o What rhythm is the patient in, and what does that mean?

- o Rate ________________
- o P waves present (yes or no)
- o Regular or Irregular rhythm (yes or no)
- o Identify Rhythm ______________

o Is the patient having an MI (yes or no), how you can tell?

o What does the BNP tell us?

o Do we have concerns with the Echo results?

o Does the patient have hyperglycemia?

o Why does the patient have edema?

o Is the patient having an exacerbation of heart failure (if so, right or left, reduced ejection fraction or preserved ejection fraction)?

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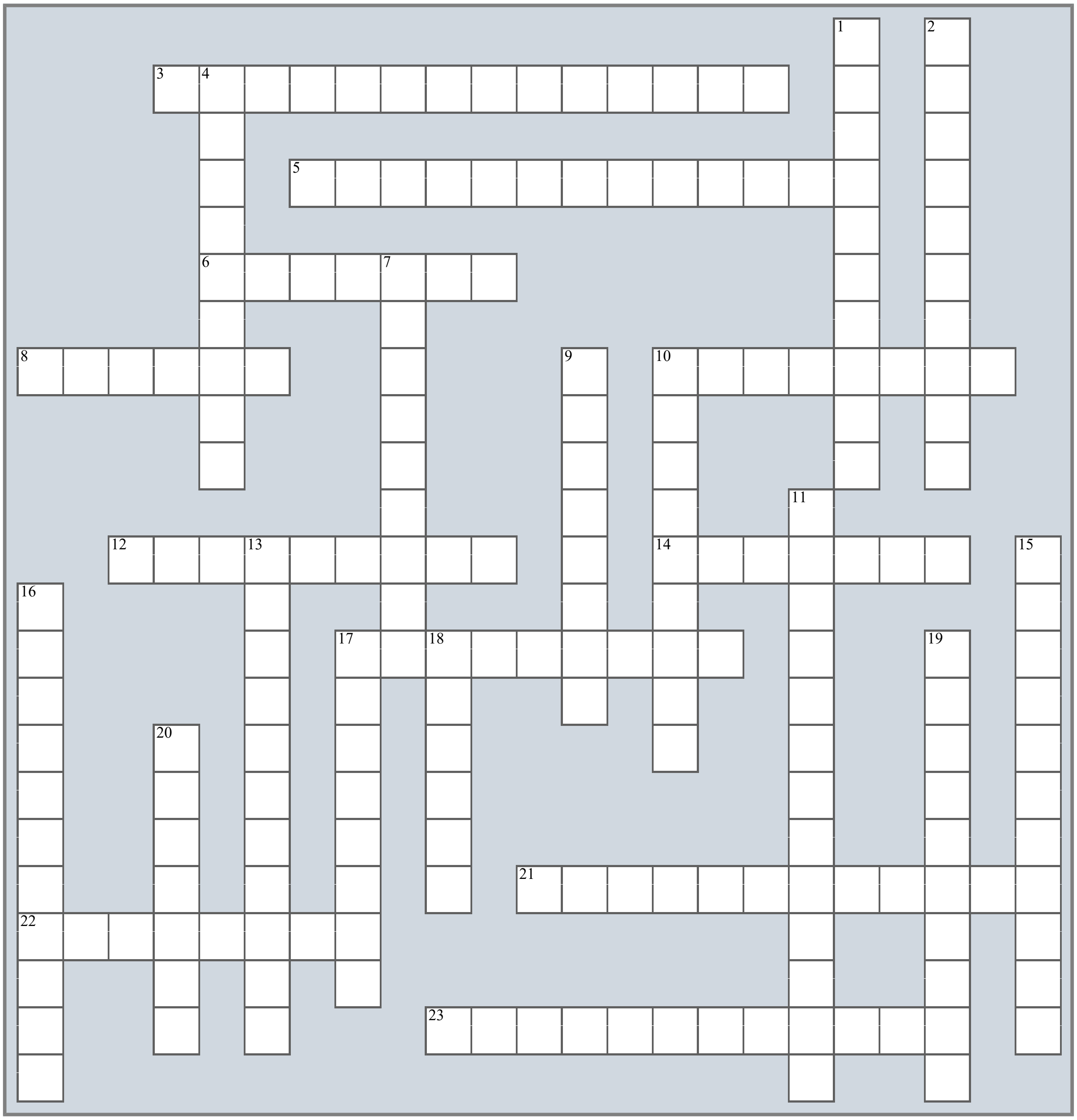
HAPS Educator Crossword 7: Reproductive System

(For an online version CLICK HERE.)



ACROSS

3. Diploid stem cell for spermatogenesis
5. Trigger for resumption of meiosis II in oocytes
6. Degeneration of an ovarian follicle is referred to as follicular . . ..
8. Term that refers to a fertilized egg
10. Sac on the head of a sperm that contains enzymes to digest pathway through zona pellucida
12. The dartos and . . .. muscles help to regulate testicular temperature
14. Region of oviduct where fertilization occurs
17. The tight junctions connecting Sertoli cells create a basal compartment and an . . .. compartment
21. Pregnancy hormone that has a relaxing effect of smooth muscle
22. Fingerlike processes that extend from the infundibulim of the oviduct
23. Layer of endometrium that is shed during menstruation is the stratum . . ..

DOWN

1. The corpus . . .. immediately surrounds the urethra
2. Immature sperm spend about 3 weeks travelling through the . . ..
4. Anterior pituitary hormone that stimulates milk production
7. Haploid germ cell that has not yet completed spermiogenesis
9. Posterior pituitary hormone that stimulates uterine contractions
10. Enzyme that converts an androgen to an estrogen
11. The . . .. glands produce a mucus-rich secretion prior to ejaculation
13. The broad ligament consists of the mesovarium, the mesosalpinx and the . . ..
15. Precursor for all steroid hormones
16. The . . .. plexus is the name given to the network of testicular veins
17. General name for C-19 steroids including testosterone and androstenedione
18. The . . .. cells are the cells in the testis that produce testosterone
19. Stage at which an embryo begins to implant in the wall of the uterus
20. Hormone produced by Sertoli calls and granulosa cells that reduces FSH secretion

CLICK HERE for Answer Key

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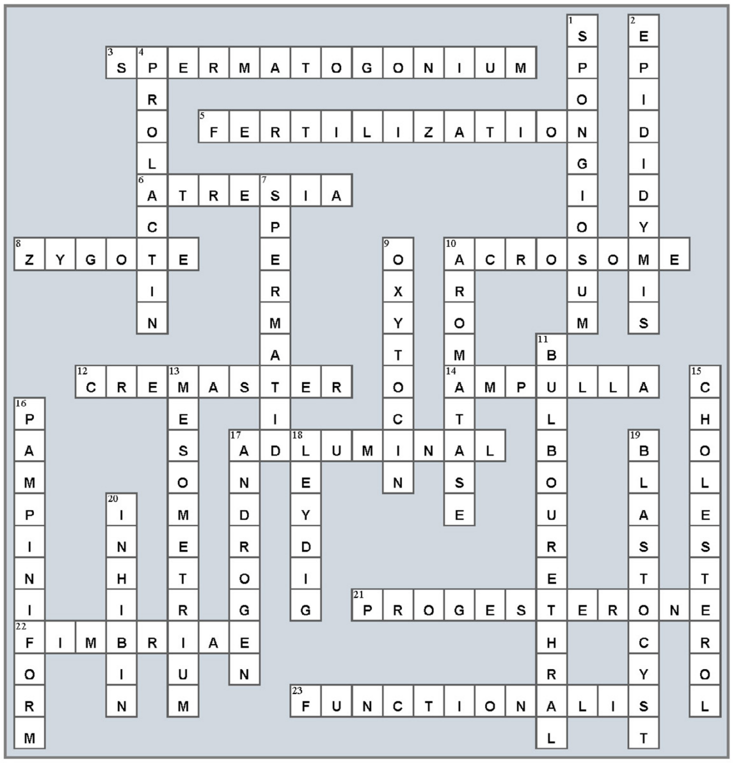
Answer key for: Crossword 7. Reproductive System (from previous page)



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Standing Committees:

2026 ANNUAL HOST COMMITTEE

Todd Gordon

This committee is in charge of coordinating the 2026 Annual Conference to take place in Kansas City, Kansas

ANATOMICAL DONOR STEWARDSHIP

Jeremy Grachan

This committee is charged with developing, reviewing, and recommending policies and position statements on the use of cadavers for human anatomy and physiology education in colleges, universities and related institutions.

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This committee recognizes talented HAPS Members through achievement awards, conference travel awards, and scholarships for HAPS-I.

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Caitlin Burns

This committee is tasked with helping HAPS establish its voice in a technological landscape shaped by social media. Committee members work closely with the Marketing Committee to facilitate connections within HAPS as well as recruiting potential members via social media.

CONFERENCES

Beth Eischen

This committee actively encourages HAPS members to consider hosting an Annual Conference. We provide advice and assistance to members who are considering hosting an annual conference.

CURRICULUM & INSTRUCTION

Abbey Breckling

This committee develops and catalogs resources that aid in anatomy and physiology course development and instruction.

DIVERSITY, EQUITY, AND INCLUSION

Jennifer Stokes

This committee has the goal of creating spaces of belonging and accessibility for all members by embracing diversity and promoting equity and inclusion.

FUNDRAISING

Stacey Dunham

This committee supports HAPS and its members by seeking donations from those within the organization as well as external funding sources.

Click here to visit the HAPS committees webpage.

Special Committees and Programs:

WELCOMING AND BELONGING

Chasity O'Malley & Caitlin Hyatt

This committee identifies opportunities for member recruitment, retention, and engagement that foster an inclusive and welcoming environment promoting professional and personal growth.

STEERING

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This committee consists of all committee chairs. It coordinates activities among committees and represents the collective committee activity to the HAPS BOD.

HAPS EDUCATOR

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This committee is responsible for publishing spring, summer and winter editions of the HAPS Educator, the journal of the Human Anatomy and Physiology Society. The committee works closely with the Steering Committee and the President of HAPS.

EXAM PROGRAM LEADS

Valerie O'Loughlin

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This committee is a closed program managed by three Program Leads (Anatomy, Physiology, Anatomy & Physiology) that is charged with developing, maintaining, securing, and managing the HAPS standardized exams.

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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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