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Staying Hydrated - A Comparative Analysis of Humectants in Human Cadaveric Tissue

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Abstract

Humectants are an important class of compounds that attract and retain water within cells. When humectants are mixed with water to create wetting solutions, they prevent desiccation of cadaveric specimens. Recognizing a relative scarcity of comparative studies analyzing the effectiveness of various wetting solutions on post-preservation cadaveric maintenance, we utilized wet-dry analysis in order to compare the effects of four common humectants (2-phenoxy ethanol, propylene glycol, ethylene glycol, and glycerol) on water retention in human cadaveric brain, cardiac muscle, liver, lung, skeletal muscle, and skin tissue. We created a concentration gradient for each humectant to identify the optimal concentration of each compound for water retention. Afterward, we directly compared water retention at the optimal concentrations of each humectant under standardized conditions. Through this simple assay, we showed that all types of cadaveric tissues submerged in concentrations of 13-15% glycerol resulted in the most retained moisture. This study addresses a significant gap in the scientific literature regarding the use of humectants in anatomical preservation. Our results will provide anatomy educators and lab technicians with evidence-based guidance for selecting the most effective humectants for their preservation needs, contributing to improved cadaver quality and educational outcomes. https://doi.org/10.21692/haps.2025.023

Key words: humectant, cadaver, tissue, anatomy, preservation

Introduction

Teaching anatomy courses are a central element of learning in medical training programs including those for physicians, physician assistants, medical scientists, nurses, and anatomists (Memon, 2018). Although cadaveric dissection is still considered the 'gold-standard' of anatomy learning, there has been a decrease in body donation due to various factors, including the COVID-19 pandemic and reduced interest in donation (Bagian et al., 2024; Manzanares-Cespedes et al., 2021; Rokade & Gaikawad, 2012; Saw, 2018). Additionally, the field has evolved to include alternative methods to ultimately reduce the need for cadavers (Burr et al., 2019; Dissabandara et al., 2015; Estai & Bunt, 2016; McBride & Drake, 2018; Simpson, 2014; Thompson & Marshall, 2019; Zargaran et al., 2020). These changes have occurred due to the development of teaching resources such as virtual simulation, anatomy applications, plastination, permanently preserved prosections, and imaging technologies such as ultrasound, computer-based learning, and virtual reality simulations (Estai & Bunt, 2016; Ghosh, 2016; Said Ahmed, 2023; Zargaran et al., 2020). However, reports show that many schools, after shifting away from dissection-based anatomical education, have reimplemented the use of cadaver labs after only a short time (Ghosh, 2016; Memon, 2018). This shift likely represents learning benefits from cadaver-based anatomy that has yet to be overcome by these noteworthy innovations.

Cadaver use in anatomy labs has also decreased due to the difficulty and cost of obtaining, preparing, and maintaining specimens (Richardson et al., 2021; Riederer, 2016; Varner et al., 2021). In addition, recent complications resulting from the COVID-19 pandemic introduced a multitude of novel challenges to the anatomical donation process, ultimately reducing the number of cadavers available to anatomy labs (McCumber et al., 2021; Singal et al., 2020).

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Once in a lab, cadavers have a relatively short life span due to natural desiccation, or water loss, from the tissues. The length of time a cadaver is used depends on the needs of the lab within a determined period of time that is set by the body donation program. On average, a cadaver may be used in a teaching lab for one to two years with some cadavers remaining in useable condition for up to eight to ten years. Time can impact the educational capabilities of the cadavers because drying alters the tissue coloring, causes the muscles to stiffen, and reduces the mobility of the cadaver. Because of this challenge, humectants are used to create wetting solutions, which can aid moisture retention in cadavers and specimens. Through our experience in anatomy labs, it is common for participants to be instructed to regularly spray cadavers with a wetting solution, sometimes even utilizing audible time-based alarms to ensure that specimens are regularly sprayed.

Outside of anatomy labs, humectants are considered one type of 'modifying agent' used with a variety of embalming techniques to increase the effectiveness of preservation (Balta et al., 2015; Brenner, 2014). When mixed with water to create wetting solutions, hydroxyl groups on the humectants form hydrogen bonds with water molecules, creating more stable intramolecular forces which prevent evaporation of water and, in this way, hydrating the tissue (Crowther, 2021; Harwood et al., 2022). Humectants are frequently used in cadaver labs, but research demonstrating their effectiveness is scant. A review of the literature revealed that much of the research regarding humectants was limited to skincare and food preservation functions, with little to none focused on their use in anatomy labs. Hence, anecdotal experience and word-of-mouth communication between anatomists, rather than scientific data, has been driving the selection of humectants.

Motivated to fill this gap in scientific knowledge, associates from anatomy labs at Brigham Young University (BYU), conceptualized, directed, and performed a comparative study using common humectants such as: 2-phenoxyethanol, propylene glycol, ethylene glycol, and glycerol (Balta et al., 2015; Brenner, 2014; Harwood et al., 2022). To determine the effectiveness of humectants for specific tissues, we tested samples of skin, skeletal muscle, brain, cardiac muscle, liver, and lung tissue. It is hypothesized that glycerol, as a humectant, will show the greatest efficacy in retaining water across the different tissue samples when compared to the other tested humectants. Our aim was to provide useful information by which cadaver labs could make informed decisions on which humectant is most effective for the needs of that lab.

Methods

Tissue Preparation

Each cadaveric tissue was first stripped of fascia, adventitia, and adipose tissue before being sectioned into equal-sized pieces. Skin samples were cut using a 1 cm diameter leather punch, while skeletal muscle samples were sectioned into 1 cm^2 squares using a scalpel and template. Brain, cardiac muscle, liver, and lung tissue were all sectioned into 0.5 cm^2 pieces using the same process as for skeletal muscle. All samples were stored for 12 to 48 hours in airtight containers until used for experimentation.

All tissue samples were provided by the University of Utah Body Donor Program and were harvested before the use of any wetting solution. Cadavers from which tissue samples were taken were all fixed with a formaldehyde-based preservative.

Solution Preparation

Wetting solutions were prepared using a volume/volume ratio of humectant to distilled water. Using 20 mL scintillation vials, we prepared 20 mL of each whole number volume/volume concentration from 5-15% for each humectant using distilled water as the diluting agent. Solutions of 2-phenoxyethanol (Fisher Scientific), propylene glycol (VWR Life Science), and ethylene glycol (VWR Life Science) were prepared following this process. Due to the viscosity of glycerol (Fischer Scientific), the 5-15% solutions were prepared using a 50% rather than a 100% glycerol solution. The solutions were stored for 12 to 48 hours in air-tight containers until use.

Procedures

Culture tubes (12 x 75 mm) were numbered and filled with 1 mL of their assigned wetting solution concentration. For experiments with skin tissue, we performed five replicates for each concentration. All other tissues had four replicates per concentration. Four test tubes with distilled water were used as a control with each experiment. After the test tubes were filled, one piece of sectioned tissue was placed in each, fully submerged in the solution. All the test tubes were then stored in a fume hood at 18°C.

After 24 hours, samples were removed from the fume hood. The tissue was removed from the solution, gently rolled on a dry paper towel to remove excess wetting solution and placed in the preweighed two dram vial and weighed again to determine tissue weight (Denver Instrument Company, Mettler Toledo Balance). Tissue wet weight was determined by subtracting the mass of the preweighed dram vial from the weight of the vial with the tissue in it. This was done for all the tissue samples. Once all samples were transferred into the glass vials, the samples were put into a 60°C mini incubator (Labnet International Inc.) for 12 hours (Folkesson et al., 1991; Kitamura et al., 2001).

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After 12 hours, the vials were removed from the incubator and weighed again. The weight of each vial and the initial vial mass were used to calculate the final tissue mass. Using these values, we calculated the percent change of each tissue (McDonald et al., 2006) and percent water retention (100 - percent change).

This procedure was done twice for each of the four humectants, resulting in eight sample replicates for each wetting solution concentration. The results of the two concentration gradient trials for each humectant were averaged together to show which wetting solution concentration retained the most moisture. The two most effective concentrations from the four humectants, eight total, was then used in a comparison trial, with the earlier procedure still followed. Following two experimental replicates of the comparison trials, the water retention across humectant and concentration were compared to determine which was the most effective. The methodology was repeated for each of the cadaveric tissues.

Analysis

After the comparison trials were completed, the same process was followed to determine the average water retention for each of the humectants. Statistical analysis was performed using Microsoft Excel. The multiple groups were compared by one-way ANOVA followed with post-hoc tests by performing separate t-tests and then the Bonferroni correction method. *P*-values of $\leq$0.05 were considered statistically significant.

Results

Various cadaveric tissues commonly found in anatomy labs were used to evaluate the effectiveness of different frequently used humectants in retaining water, compared to a control. Across all tested tissue types, wetting solutions of 13%, 14%, and 15% glycerol consistently demonstrated significantly greater water retention than the control. Figures 1-6 illustrate these findings, along with several other statistically significant differences between the control and individual humectants.

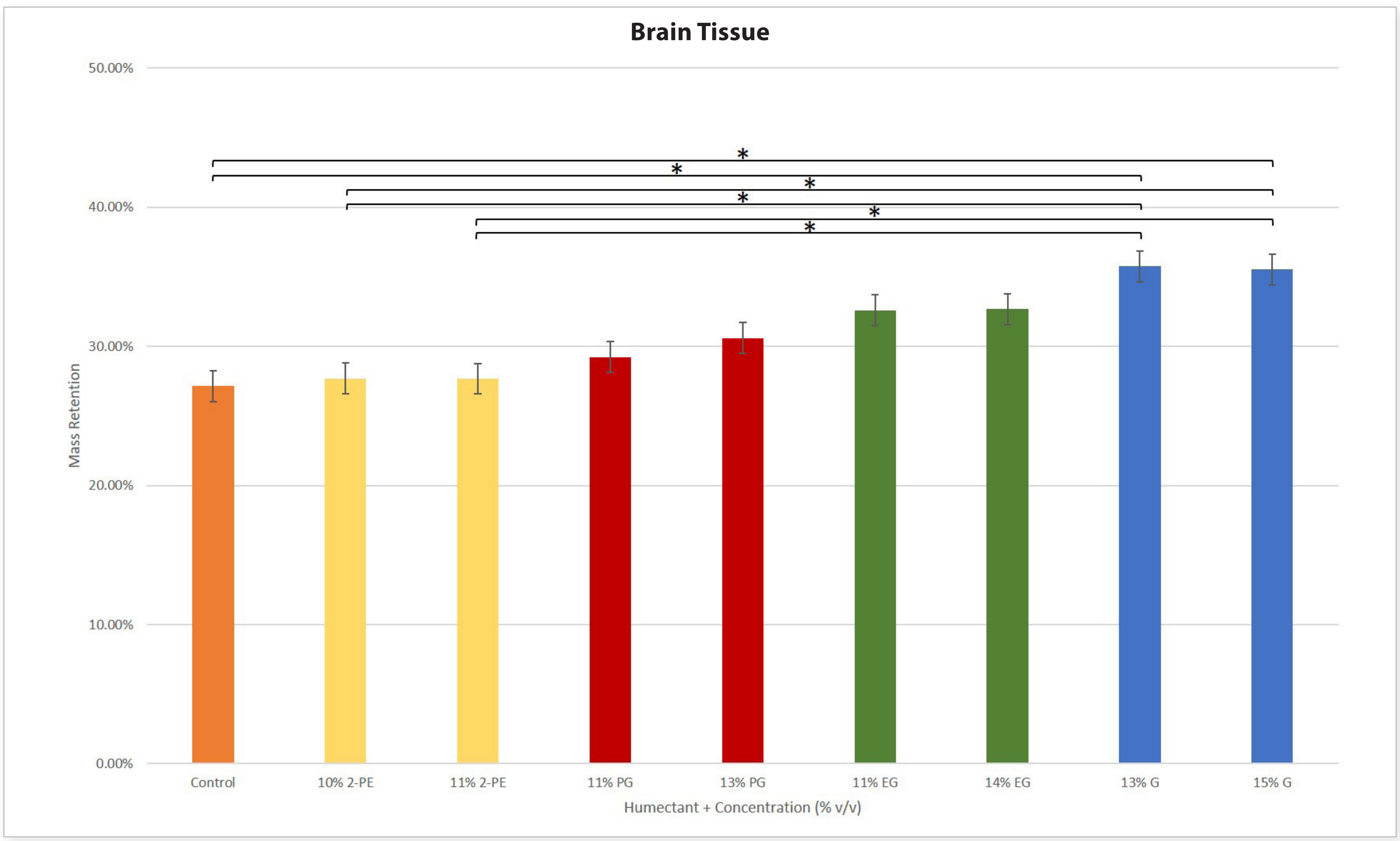

Figure 1. *Comparison trial results for cadaveric brain tissue. The humectant concentrations tested are 10% and 11% 2-phenoxyethanol, 11% and 13% propylene glycol, 11% and 14% ethylene glycol, and 13% and 15% glycerol. Parallel bars represent the mean* $\pm$ *standard error, *two-sided p value* $\leq$*0.05 with the unequal variance t-test.*

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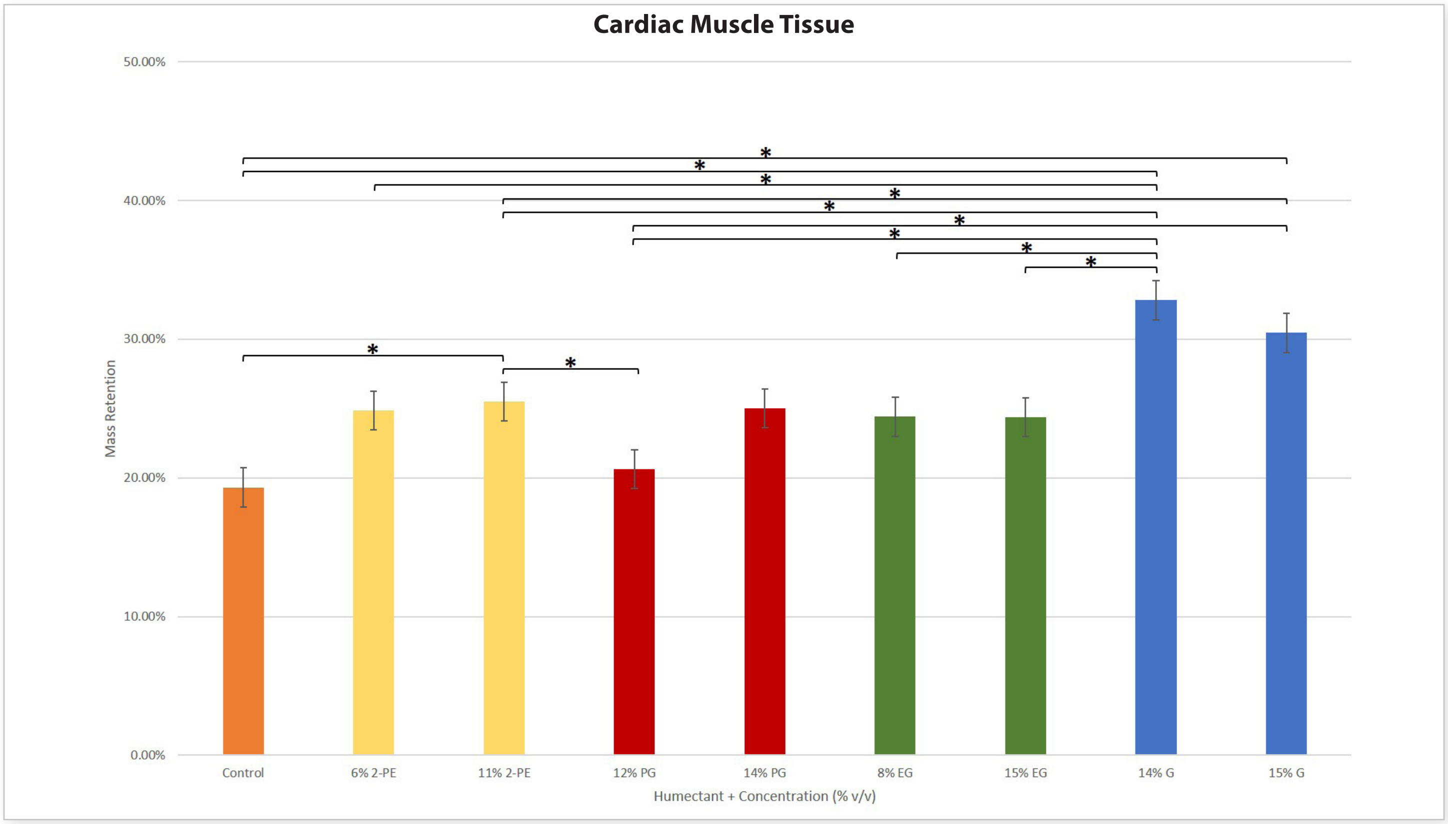

Figure 2. *Comparison trial results for cadaveric cardiac muscle tissue. The humectant concentrations tested are 6% and 11% 2-phenoxyethanol, 12% and 14% propylene glycol, 8% and 15% ethylene glycol, and 14% and 15% glycerol. Parallel bars represent the mean ± standard error, *two-sided p value ≤0.05 with the unequal variance t-test.*

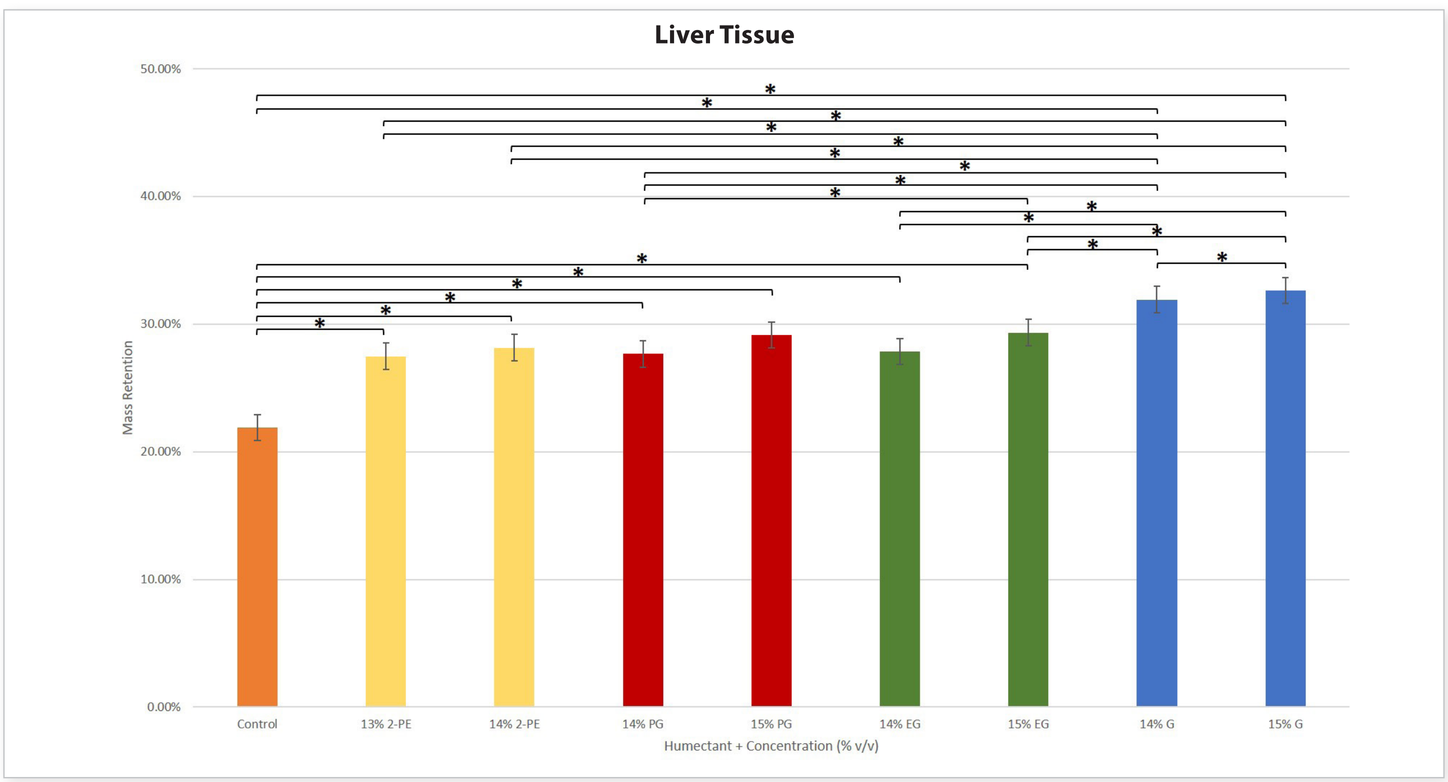

Figure 3. *Comparison trial results for cadaveric liver tissue. The humectant concentrations tested are 13% and 14% 2-phenoxyethanol, 14% and 15% propylene glycol, 14% and 15% ethylene glycol, and 14% and 15% glycerol. Parallel bars represent the mean ± standard error, *two-sided p value ≤0.05 with the unequal variance t-test.*

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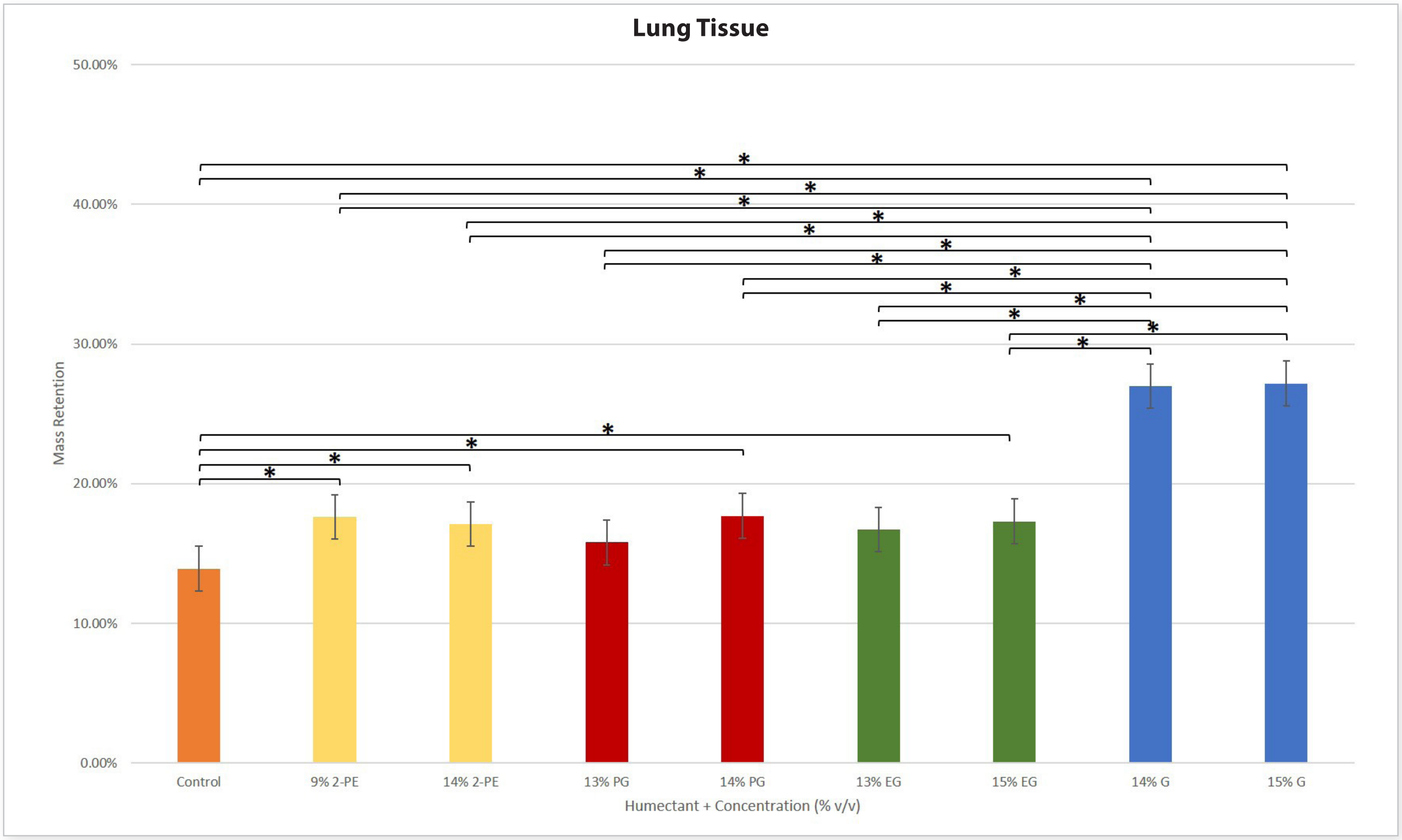

Figure 4. *Comparison trial results for cadaveric lung tissue. The humectant concentrations tested are 9% and 14% 2-phenoxyethanol, 13% and 14% propylene glycol, 13% and 15% ethylene glycol, 14% and 15% glycerol. Parallel bars represent the mean ± standard error, *two-sided p value ≤0.05 with the unequal variance t-test.*

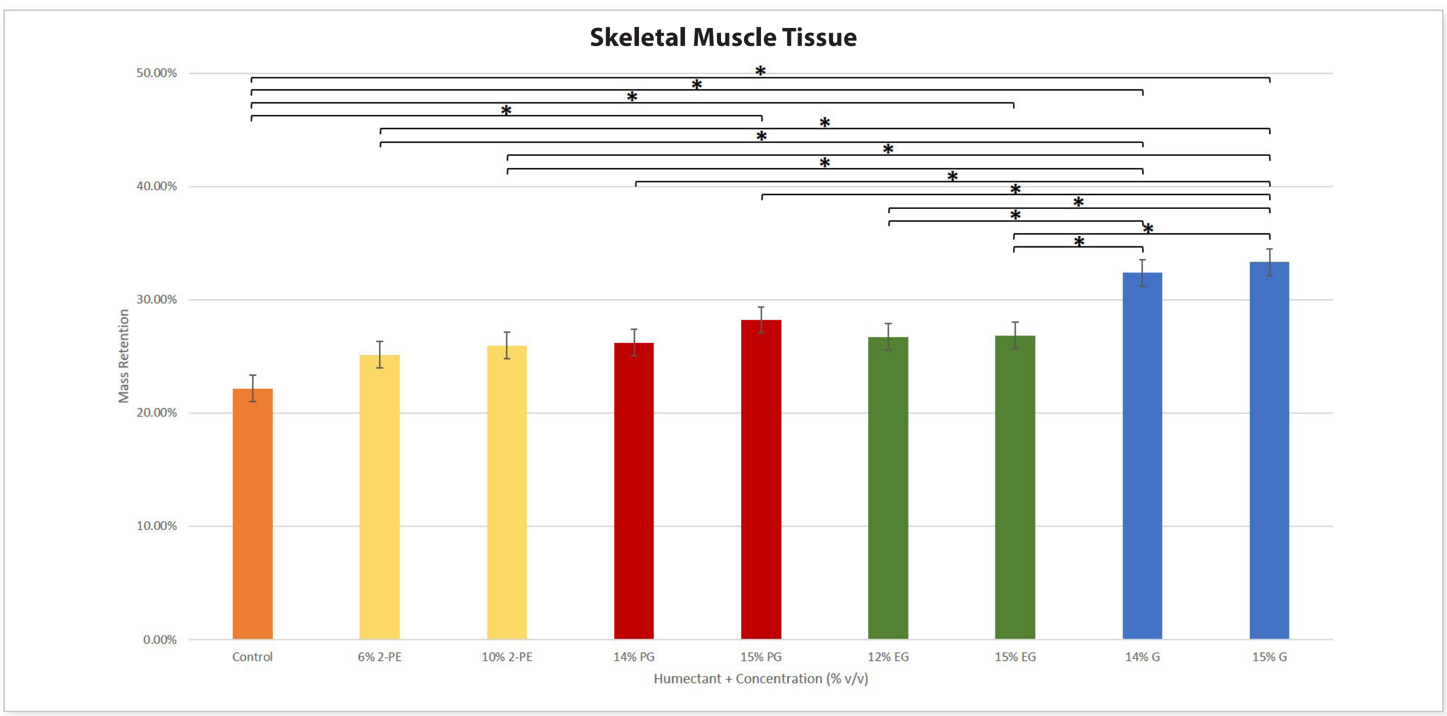

Figure 5. *Comparison trial results for cadaveric skeletal muscle tissue. The humectant concentrations tested are 6% and 10% 2-phenoxyethanol, 14% and 15% propylene glycol, 12% and 15% ethylene glycol, 14% and 15% glycerol. Parallel bars represent the mean ± standard error, *two-sided p value ≤0.05 with the unequal variance t-test.*

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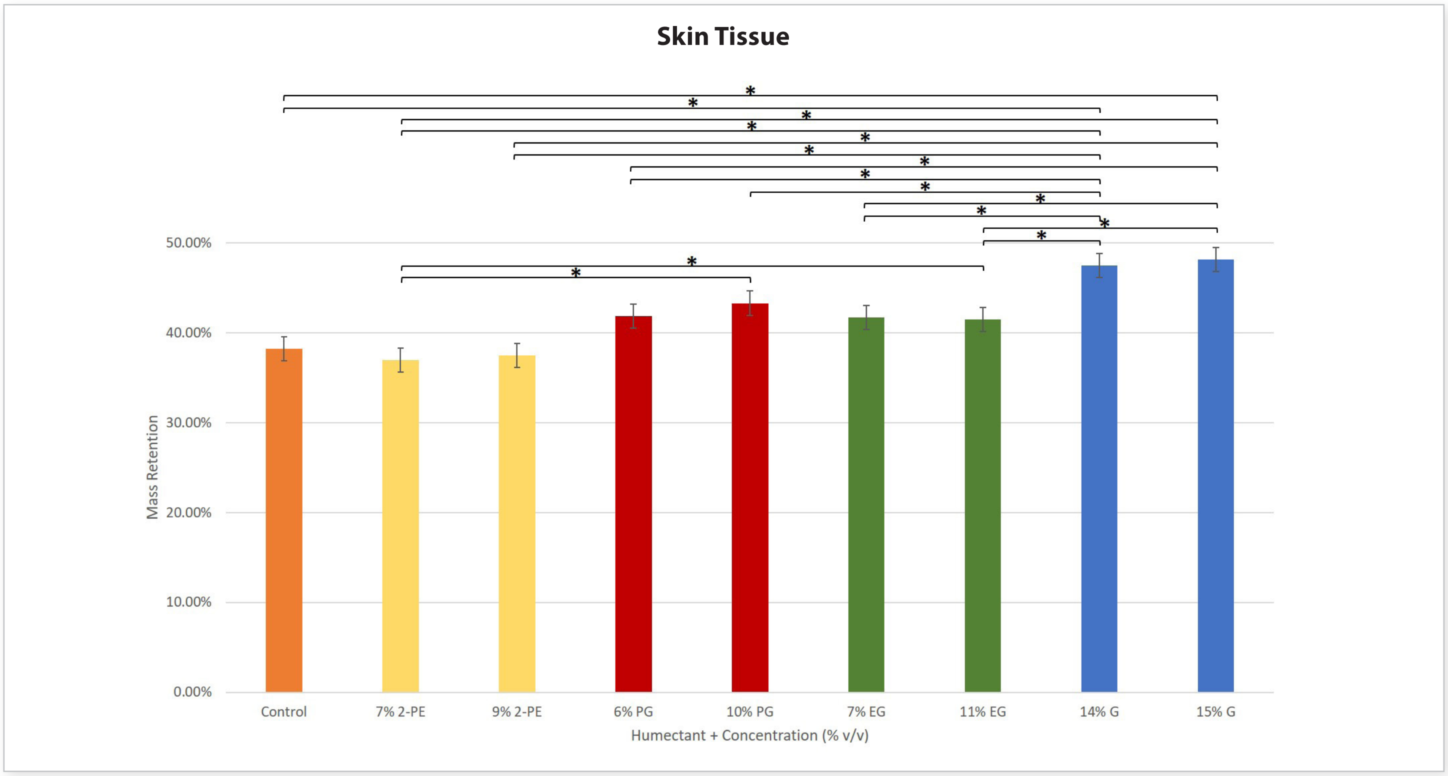

Figure 6. *Comparison trial results for cadaveric skin tissue. The humectant concentrations tested are 7% and 9% 2-phenoxyethanol, 6% and 10% propylene glycol, 7% and 11% ethylene glycol, and 14% and 15% glycerol. Parallel bars represent the mean ± standard error, *two-sided p value ≤0.05 with the unequal variance t-test.*

With regard to brain tissue, comparison showed that wetting solutions of 13% and 15% glycerol were significantly more effective at retaining water in the tissue than the control (Figure 1). Cardiac muscle tissue retained water significantly better in wetting solutions of 11% 2-phenoxyethanol, 14%, and 15% glycerol compared to the control (Figure 2). With regard to liver tissue (Figure 3), comparison showed that wetting solutions of 13% and 14% 2-phenoxyethanol, 14% and 15% propylene glycol, 14% and 15% ethylene glycol, and 14% and 15% glycerol were significantly more effective at retaining water in the tissue than the control.

Lung tissue retained water significantly better in wetting solutions of 9% and 14% 2-phenoxyethanol, 14% propylene glycol, 15% ethylene glycol, and 14% and 15% glycerol compared to the control (Figure 4). Comparison showed that skeletal muscle tissue retained water significantly better in wetting solutions of 15% propylene glycol, 15% ethylene glycol, and 14% and 15% glycerol than the control (Figure 5). Finally, with regard to skin, wetting solutions of 14% and 15% glycerol were significantly more effective at retaining water in that tissue compared to control (Figure 6).

Discussion

Humectants are valuable compounds used in anatomy labs to retain moisture within cadaveric tissue. There is a limited amount of research about which humectant at which concentration is the most effective at retaining moisture, so this research is valuable for cadaver labs to ensure the best preservation of their specimens. By improving preservation efforts there can be increased use of cadavers, improving the education of students in a variety of programs (Ghosh, 2016; Memon, 2018).

In the concentration gradient trials the general trend observed, specifically in propylene glycol, ethylene glycol, and glycerol, was that more water tended to be retained as humectant concentration was increased. This trend was observed across all six cadaveric tissue types. When looking at the tissue specific comparison trials, the general trend seen for water retention was glycerol retaining the most and 2-phenoxyethanol the least. Propylene glycol and ethylene glycol then alternated as second and third most effective water retention agents depending on the tissue.

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Overall, our data revealed that cadaveric tissues submerged in wetting solutions of 13-15% glycerol retained more moisture than tissues submerged in wetting solutions composed of varying concentrations of other humectants and those submerged in distilled water alone. This information can be used in anatomy labs to select the humectant and concentration best suited to their lab's purpose and continue the use of cadavers in education.

One of the main limitations of our research is extrapolating the results of this research to an educational cadaver lab environment. While we strove to mimic the environment of this type of lab by soaking the tissue samples and placing them in an incubator, the reality of lab conditions can vary widely. At BYU, cadavers may be directly exposed to air for 12-15 hours per day for five to six days a week, while being sprayed with a wetting solution every five to ten minutes. Furthermore, the relative changes in air humidity, building airflow, student handling, ambient temperature could all introduce confounding environmental effects. In addition to this, the fume-hood, although maintaining a relatively dry environment, may still have had alterations in humidity due to climate. Other considerations are due to variations in the cadaveric tissue, such as initial state of the tissue, genetics and health of the donor, and other extraneous influences such as conditions in transport and preservation of the tissue.

It should be noted that certain anatomy labs submerge the cadavers and/or prosections in a wetting solution, while other anatomy labs use a wetting solution spray on the cadavers and/or prosections. In this experiment, we elected to submerge the tissue in a humectant as it closely mimics the former practice and because we thought it would be more difficult to standardize the amount of humectant applied to the tissue when using a spray compared to submersion. Future experiments may include the spraying method instead.

Other limitations can be attributed to the scope of our research. Our experiments were restricted to four humectants and 11 concentrations of each. Expanding the number of humectants and range of concentrations tested would increase the potential findings of this study. Likewise, our study did not include other tissue types such as bone, fat, gastrointestinal organs, and kidneys, which can potentially be further explored.

The next step in this area of research would be completing a cost-benefit analysis of the different wetting solutions. Such an analysis would be useful for anatomy labs to determine if the difference in water retention based on the humectant and its concentration can be justified for the price based on the number of and usage frequency of cadavers in an individual lab.

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What Makes Non-Didactic Sessions Effective? Facilitator Preparations and Student Perspectives

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Abstract

Non-didactic learning is an integral part of health sciences curricula. Previous analyses have evaluated non-didactic instruction by reviewing student comments in end-of-course evaluations. While useful, these analyses lack faculty perspective and granularity of individual session feedback. This pilot cross-sectional survey and thematic analysis study examines the non-didactic small group experience at a multi-campus medical school by: 1) analyzing faculty perspectives via an anonymous survey and 2) reviewing student comments from individual non-didactic small group sessions. Our faculty sample included 153 faculty responses, and the individual session feedback included over 2000 student comments. Students reported that cohesive content-focused session materials are critical, particularly at multi-campus schools. Faculty reported consistent preparation for sessions, but little training in non-didactic instruction. In particular, faculty were interested in more training on engaging students. These findings suggest an important role for facilitator training and content preparation in non-didactic learning sessions to improve the learning experience for both students and faculty facilitators. https://doi.org/10.21692/haps.2025.024

Key words: active learning, facilitation, professional development, non-didactic learning

Introduction

Active learning in non-didactic sessions is widespread and constitutes an important part of anatomy and physiology instruction, as well as health sciences education as a whole (Burgess et al., 2014, 2020; Dolmans et al., 2015; Fatmi et al., 2013; Huang et al., 2019; Kitchen, 2012; Reimschisel et al., 2017, Xiao, 2024). Working in groups provides opportunities for learners to work collaboratively and share information to foster multidisciplinary integration, which is essential within healthcare settings. Non-didactic sessions encourage students to engage in active information processing in personal and meaningful ways (Challa et al. 2021).

Non-didactic learning is designed to be learner-focused. Therefore, soliciting student impressions of this learning is critical (Steinert, 2004). Importantly, active learning also depends upon effective facilitation (Prasad & O'Malley, 2022). Despite evidence supporting active learning as a superior pedagogical approach in the classroom, many instructors favor more traditional teaching methods (Handelsman et al., 2004; Stains et al., 2018). Facilitators often come from diverse educational backgrounds, with many not having experienced active learning as either learners or educators (Du et al., 2022). Though professional development opportunities may be available, implementing different pedagogical approaches often proves difficult, suggesting perhaps that adequate training of fundamental concepts of active learning is necessary for success (Kitchen, 2012).

Previous research has focused on the effectiveness of small group instruction by reviewing student comments in end-of-course evaluations (e.g., Arja et al., 2020; Burgess et al., 2014; Holland & Pawlikowska, 2019; McClurg et al., 2015; Sahu et al., 2018). While useful, this work misses the faculty perspective on these sessions and the granularity

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of examining individual session feedback at the time of its completion. It is our contention that continuous feedback from both the learner and faculty as to the effectiveness of teaching strategies is vital in providing the best educational experience to students. Our research examines the non-didactic, small group experience in two ways: 1) analyzing faculty perspectives using an anonymous survey and 2) reviewing student feedback submitted for individual sessions within multiple courses.

Methods

Setting

This pilot was done at Indiana University School of Medicine (IUSM), a nine-campus allopathic medical school with approximately 375 students per class with a distribution of 20-180 students per campus. All 9 regional IUSM campuses followed a discipline-based curriculum from the 1970s until 2017, when the curriculum was restructured into an integrated design with approximately two years focused on the foundational sciences, clinical skills, and health systems science followed by two years focused on clinical rotations (clerkships) and electives. All courses are required to have no more than fifty percent of their time devoted to didactic lectures, thus non-didactic learning is abundantly used throughout. Didactic content is delivered via recorded lectures. Non-didactic content is most commonly delivered via case-based exercises or team-based problem sets discussed within a small group setting of 4-8 students and facilitated as an entire cohort (i.e., all the students on that campus) by one or two instructors. The facilitator/student ratio varies across the nine campuses. The materials for the non-didactic sessions are pre-made by a course management team (CMT) to ensure that learners at all campuses are participating in equivalent experiences and receiving the same information.

Faculty survey

The faculty survey was developed by the research team and piloted with two additional faculty members to help establish face and content validity. These faculty completed the survey and provided feedback on item clarity and flow. The associated feedback was then implemented, and the survey was finalized. The final survey included basic demographic information as well as questions regarding course involvement, session type, prior facilitation training, and regular preparation habits. The survey was administered via Qualtrics (Qualtrics, Provo, UT) to all faculty involved in facilitation in any of the pre-clerkship courses and at any of the campuses. Basic descriptive analysis of the survey (Counts, Percentages) was then done via Microsoft Excel and inferential statistics using SPSS version 29.0 (IBM Corp, Armonk, NY). The faculty survey administration was approved by the Indiana University Institutional Review Board (IRB) as protocol #18066.

Student comments

Students were asked to provide feedback on each non-didactic small group session in eight of the medical knowledge-focused pre-clerkship courses during the 2021-2022 academic year. Feedback was collected via an optional Qualtrics survey link and QR code for each session. The survey employed a 5-point Likert scale (Strongly Agree - Strongly Disagree) and consisted of the following three questions along with a session comment box:

- Which small group are you evaluating today?
- What campus are you on?
- This small group improved my understanding of course content.

In one course on the largest campus, students also received paper copies of the survey with each session. When both online and paper surveys were examined, the same codes and themes were identified in both, thus all analyses include both paper and online survey data. Analysis of the anonymous student comments was deemed non-human subjects research by the Indiana University IRB as protocol #17170.

Thematic analysis was utilized to evaluate student feedback. Members of the research team independently reviewed comments from one course to establish a codebook for coding all comments (Appendix 1). Once the codebook was established, two scorers independently reviewed comments within each course and categorized comments as positive, neutral, or negative and then with a subtheme of preparation (prior to class), atmosphere (during class), and communication (outside of class). Preparation was then further divided into separate codes for student, facilitator, content, or other. All comments were reviewed and discrepancies were discussed by the research team until consensus was reached. Once all comments were categorized, the coded data was revisited to establish the most frequently occurring codes and identify exemplar quotes for each.

Results

Sample

The faculty survey yielded 126 responses that were relevant to this analysis. This sample included faculty from all campuses and represented all relevant pre-clerkship courses (see Table 1). Most respondents (69%) indicated that they were involved in both didactic (pre-recorded lecture) and non-didactic (small group) facilitation of the curriculum while 31% indicated that they were only involved in non-didactic facilitation. In addition, 31.7% of respondents indicated that they were also involved in course management across the campuses. Faculty appointment types ranged from adjunct (20.6%) and part-time (15.1%) to full-time faculty (63.5%).

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Years of experience facilitating non-didactic sessions also varied within the sample from less than one year to more than six (when the current curriculum model was put into place). The most common response was greater than six years (54.8%) experience, followed by three to four years (20.6%). One to two years of facilitating experience was reported by 9.5% of respondents.

Appointment Type	N	%
Adjunct faculty	26	20.6
Full-time faculty	80	63.5
Part-time faculty	19	15.1
Involvement	**N**	**%**
Small group only	39	31
Small group + lecture	87	69
CMT member	40	31.7
Years facilitating at IUSM	**N**	**%**
1-2	12	9.5
3-4	26	20.6
5-6	19	15.0
>6	69	54.8

Table 1. *Faculty member demographics for those that responded to the survey.*

Reported Faculty Training

Faculty responses to training on small group facilitation are demonstrated in Figure 1. When asked what topics would be most beneficial for additional training, the most prevalent responses focused on increasing student engagement (e.g., engaging all learner types, methods of encouraging rich discussion) and the use of virtual tools (e.g., how to use polling software such as TopHat, how to run a multi-room Zoom session).

Reported Faculty Preparation

Ways in which faculty report preparing for non-didactic facilitation are illustrated in Figure 2. Over 81% of respondents reported always or usually reading through the pre-made materials for their session. However, nearly 38% of respondents reported only rarely or never meeting with the director of the course and nearly 30% reported rarely or never watching the relevant lecture recordings. Additional analyses performed to evaluate the relationship of faculty perceptions or preparation relative to years of experience failed to reach statistical significance.

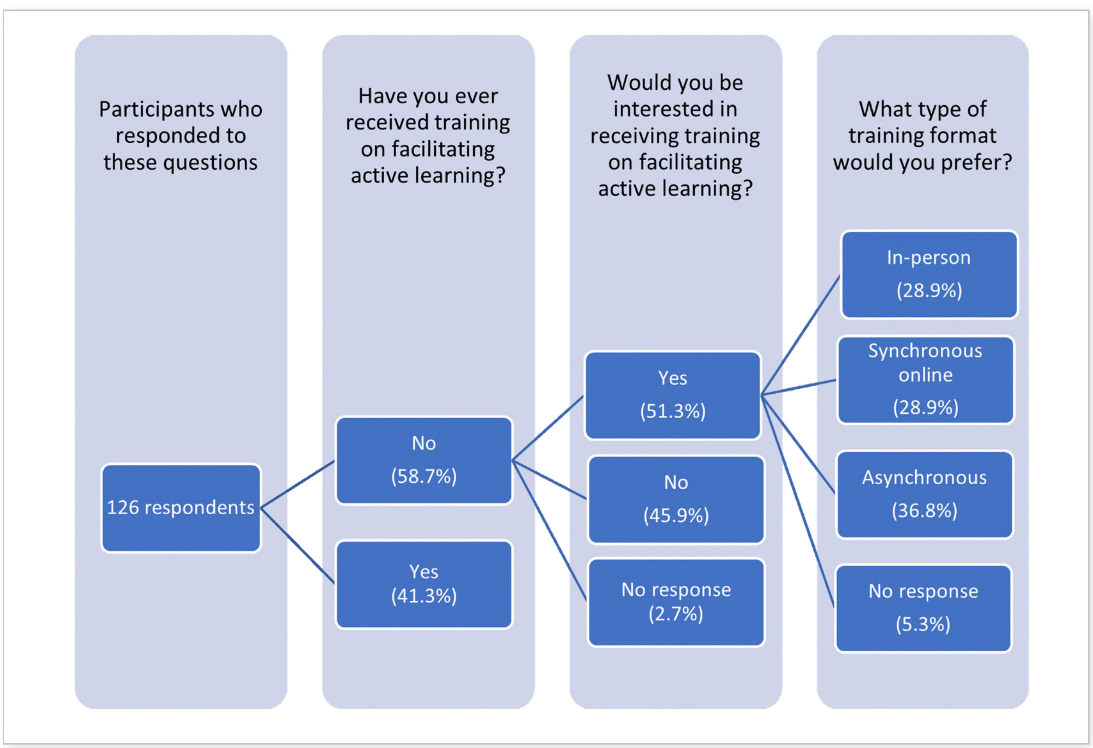

Figure 1*. Faculty Respondents' Perspectives on Facilitator Training*

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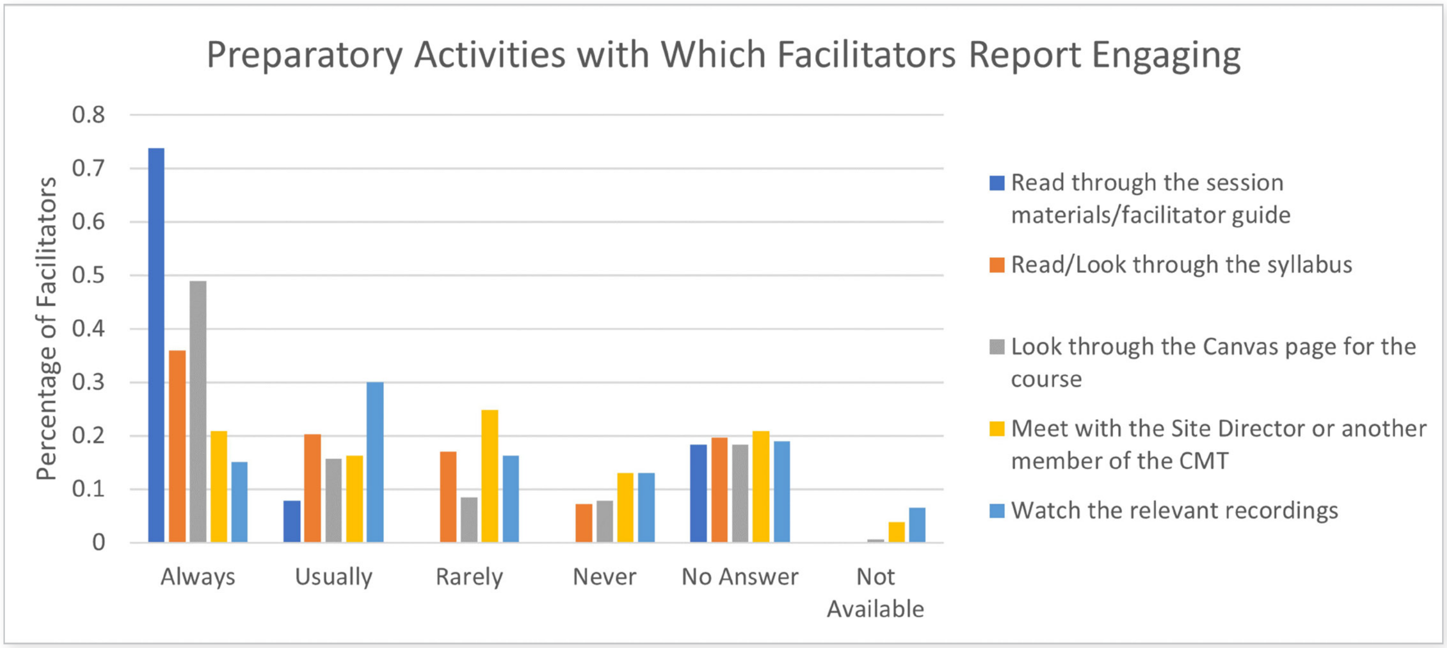

***Figure 2**. Preparatory Activity with which Facilitators Report Engaging*

Student Comments

A total of 2,908 responses including 1,643 comments were received regarding 146 non-didactic sessions in the medical knowledge courses from the first two years. From these comments, 1,955 phrases were coded. Across all the courses and campuses, the dominant theme was preparation. The coding for this theme is in Table 2. The most common code mentioned content preparation. This included the PowerPoints used during the session and any guides, keys, or summary sheets distributed to students afterward. Although much less common than comments regarding content, there were occasional comments focusing on the preparation of the facilitator. The codes of atmosphere and communication were only identified sparingly and, when further examined, tended to be either campus or instructor specific. The subcode of student preparation was also very rarely used. Thus, these codes were not further analyzed.

Discussion

Given that non-didactic sessions often synthesize information rather than simply deliver content, our faculty survey was designed to better understand the preparation and training completed by facilitators. This is particularly important in our system where the same non-didactic session will be delivered on nine campuses across the state, by many different facilitators, about a third of whom are adjunct or part-time faculty. It is not uncommon for a facilitator to be delivering only a handful of sessions throughout the entire pre-clerkship medical curriculum. Thus, facilitator training is crucial for comparability of sessions across campuses. Slightly over 50% of our faculty have more than 6 years' experience with delivering non-didactic sessions while nearly 10% of respondents have only 1 or 2 years of experience. Nearly all facilitators prepare by reading through the session materials (Figure 2), however, roughly half of respondents

Initial Classification	Code	Example quote
Positive	Content	"The slides were very well organized and easy to navigate. Manageable amount of prework. Applicable to written material"
	Facilitator	"Our facilitator was very helpful in leading us to answer without giving anything away. He also asked great questions to help us understand."
Negative	Content	"There were several discrepancies between the student guide and the facilitator PowerPoint."
	Facilitator	"None of the facilitators seemed to know what was going on… and the facilitators didn't know how to answer questions nor did they know the structure of the small group."

***Table 2.** Coding for the dominant theme of Preparation*

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would also appreciate training (Figure 1), particularly guidance on increasing student engagement and better use of educational technology. Respondents were equally split regarding receiving this training in-person, virtually, or asynchronously (Figure 1). Based on this feedback, in addition to the content-focused session guides, it may be worthwhile to prepare specific onboarding training for new facilitators and annual training in response to specific facilitator needs. This work supports Prasad and O'Malley (2022) and others, highlighting the importance of facilitator preparation in running problem-based learning sessions. For instance, Iqbal et al. (2020) propose designing entrustable professional activities (EPAs) as a roadmap for facilitators of small group sessions to aid in vertical and horizontal integration of content. Steinert et al. (2016) reviewed faculty development initiatives from 111 studies demonstrating high satisfaction with faculty development programs, with participants reporting increased confidence, enthusiasm and knowledge of different effective pedagogical approaches.

Preparation of session content was a common theme from student comments. In particular, post-session material organization and completeness was important when reviewing session material for exams and helped enable students to engage in the session rather than act as scribes to capture all the information for future review. Thus, good preparatory materials may increase student engagement, one of the facilitators' concerns. Likewise, well-designed and organized in-session materials may increase the success of facilitators by helping identify where to place focus when discussing the cases/exercises and how to lead the students through building their knowledge in a logical and connected manner. This may also serve to decrease the risk of facilitators adding tangential information that distracts from the objectives of the session or takes time away from the exercises so that there is rushing to complete the session, both lesser themes of student dissatisfaction.

Limitations

There are several limitations to this study. We did have incomplete participation in our faculty survey. The faculty listserv that the survey was sent on includes 466 email addresses on it, which would calculate to a 37% response rate. However, this list is known to include a handful of duplicate emails, all of the co-authors, and all of the pre-clerkship preceptors for whom the study may not be relevant. Thus, our potential pool of participants is smaller than the total number of emails and our response rate would be correspondingly higher. These sampling limitations resulted in some potentially interesting analysis being underpowered and therefore more comprehensive conclusions or actionable recommendations on, for example, facilitator preparation, could not be made.

In addition to the faculty participation, student participation in the session evaluations was also incomplete. Students were asked to provide feedback on each non-didactic small group session in courses during the 2021-2022 academic year. Feedback was collected via a pre-existing Qualtrics survey link and QR code for each session (though feedback for one campus/one course was collected via paper handouts). A *de novo* survey better tailored to our research question(s) may have provided value to this study and will be considered for future use. Perhaps moving forward from this pilot study, student feedback could be assessed by a required survey or even an incentivized survey, as these have been demonstrated to increase response rate (Ahmed, 2018). Further, it has been suggested that students are more willing to provide constructive feedback if they perceive their feedback will be useful in making session or course improvements (Vargas-Madriz & Nocente, 2023).

Conclusions

In conclusion, feedback from students participating in non-didactic learning modules, as well as the faculty members facilitating those modules, can provide more granularity in evaluating the efficacy of active-learning pedagogy. We contend that both students and faculty can be positively impacted by careful and deliberate planning in advance of non-didactic sessions. Faculty training should be designed to fit their needs and offered in multiple formats to engage the most faculty. We would recommend that administrations work with their faculty to provide training that is practical, interactive, and focused on their specific interests. Two consistent areas of focus in which faculty are interested include student engagement and educational technology, a sentiment most-certainly shared among educators in higher education. Utilizing a thoughtful approach to the design and delivery of non-didactic session preparatory materials can significantly enhance both the student and faculty experience during the sessions as well. With well-designed materials, a more cohesive and effective educational experience within and across multiple campuses may be facilitated. As faculty teaching duties are often fluid, the authors feel that frequent feedback from students AND faculty can help assess efficacy of content delivery quickly that allows for more efficient curricular and pedagogical changes.

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EDUCATIONAL RESEARCH

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Exploring the Impact of a Medical Terminology Course on Anatomy and Physiology Performance

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Abstract

Medical terminology is often a course recommended to undergraduate students before taking an anatomy and physiology I (A&P) course. However, empirical evidence to support the rationale for this common practice is limited in undergraduate students. The main objective of this study is to compare A&P grades of those students who have taken a medical terminology course before A&P to those who have not taken a medical terminology course. Anatomy and physiology I grades were compared in two categories, A&P grades of students who had taken a medical terminology course and A&P grades of students who had not taken a medical terminology course. In addition, for those students who had taken a medical terminology course, the time interval between medical terminology course completion and A&P course completion was noted. Analysis performed found a statistically significant difference in A&P grades of students who took medical terminology before A&P than students who did not ($p = 0.02$). However, there was no statistical significance in grades when considering the time interval between medical terminology course completion and A&P. This result seems to support the recommendation that a medical terminology course should be completed before an undergraduate student takes A&P. https://doi.org/10.21692/haps.2025.029

Key words: medical terminology, anatomy and physiology, undergraduate, prerequisite course, curriculum

Introduction

The implementation of prerequisite courses has been standard protocol for curriculum development and course mapping in higher education. Prerequisites are commonly recommended with Science, Technology, Engineering, and Math (STEM) courses (Bormann et al., 2013; Harris et al., 2004; Martin, 1989). These expectations are often based on the constructivist theory of knowledge, which postulates that old knowledge is foundational for new knowledge to be acquired (Bodner, 1986).

Introductory or general biology courses are commonly required prerequisites for undergraduate anatomy and physiology (A&P) and have been shown to strongly predict student success in those courses (Forgey et al., 2020; Harris et al., 2004). Another prerequisite often recommended is medical terminology, which introduces students to the prefixes, suffixes, and root words foundational to the language of A&P.

Much of this terminology is derived from Greek and Latin and is essential for effective communication in healthcare settings (Joskowska & Grabarczyk, 2013; Yagin & Fernandes, 2024; Chmielewski & Mozdziak, 2023). Familiarity with medical terminology is believed to provide the critical background needed to succeed in medically oriented courses such as A&P (Drury et al., 2002).

Results are mixed when comparing studies assessing the relationship between medical terminology knowledge and its effects on learning A&P. Pampush and Petto (2011) found that comprehension of Latin and Greek root words had no effect on anatomy grades of undergraduate students. However, in medical students, associations were shown between anatomy grades and exposure to medical affixes and root words (Smith et al., 2007; Stephens & Moxham, 2018). Students also felt that exposure to medical terminology helped with their understanding and mastery of anatomy (Cortés et al., 2024; Robertson et al., 2020; Souza et al., 2024; Stephens & Moxham, 2016).

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Most of the existing literature on the impact of medical terminology and A&P performance focuses on students' perceptions or short-term testing rather than examining course performance directly (Cortés et al., 2024; Robertson et al., 2020; Souza et al., 2024; Stephens & Moxham, 2016). Medical students who had studied Greek and/or Latin achieved better results in anatomy examinations (Stephens & Moxham, 2018). In addition, Smith et al. (2007) found that first-year medical students who studied medical etymologies bolstered their anatomy understanding, which also contributed to their enjoyment of the subject.

In the Anatomical Society's core syllabus, a statement is made that "knowledge of accepted general anatomical terminology is a prerequisite for learning anatomy" (Smith et al., 2016). To our knowledge however, there have been no studies to date that test this speculation by directly comparing completion of a medical terminology course and successfully performing in an A&P course among undergraduate students. In addition, there is limited information about the temporality between taking a medical terminology course and an A&P course to see any potential benefit or impact.

According to Ebbinghaus' forgetting curve, information is lost over time if we do not take measures to retain it (Murre & Dros, 2015). Therefore, the timing of the medical terminology course may also play a role in the success of an A&P course. Many medical terminology courses require rote memorization, which often is forgotten soon after the course is over. As a result, one would assume that the greater the time interval between completing medical terminology and enrolling in anatomy and physiology, the less benefit is observed. However, in undergraduate engineering students, Wilck et al. (2016) found that student success in an advanced course was not affected by the timing of the prerequisite course completion.

Another factor to consider is whether the greatest benefit is achieved when a medical terminology course is taken concurrently with an anatomy and physiology course. This seems to be logical given that the forgetting curve indicates that most retention happens within the first few hours of learning new information (Murre & Dros, 2015). However, Sveinbjornsson (2021) found no statistical difference between organic chemistry students who had taken general chemistry before versus students who had taken general chemistry during organic chemistry.

Building upon previous findings, this study aims to address the gap in the literature regarding the potential academic benefits of completing a medical terminology course prior to enrollment in undergraduate A&P. This study also addresses whether the timing of medical terminology completion relative to A&P enrollment influences this effect.

Methods

The student data for this study was obtained from a small, private midwestern university. Student grades and information were retrieved from the university's electronic student records. General student demographic information (major and year) and Anatomy and Physiology I (A&P) grades from fall semester 2020 until fall semester 2024 were utilized in this study. In addition, information on medical terminology grades and timeline was also collected. Identifiable information pertaining to each student was omitted to protect student privacy. All students were taking the A&P course for the first time. The University's Institutional Review Board approved the protocol for this study.

Anatomy & Physiology I is accessible to all students who have completed the requisite introductory courses in chemistry and biology. While it serves as a mandatory course for certain degree programs, it remains open to students across various disciplines. A&P is a required course for 298 of the 443 students in the study. The medical terminology course, which has no prerequisites, is also available to all students. Although it is part of specific academic tracks, it is not a prerequisite for Anatomy & Physiology I.

After the A&P grades were obtained, student records were examined to note whether they had taken a medical terminology course, the grade in the course, and when the course was taken (in semesters). If the student had taken the course in high school or had taken the course outside of the university, that was noted as a transfer credit (T) instead of a letter grade and therefore were not used in calculations of medical terminology grades. All letter grades were converted to a grade point average number from 4.0 to 0.0 shown in Table 1.

Letter Grade	Grade Point Equivalency
A	4.0
A-	3.7
B+	3.3
B	3.0
B-	2.7
C+	2.3
C	2.0
C-	1.7
D+	1.3
D	1.0
D-	0.7
F	0.0

Table 1. *Grade point equivalency per letter grade*

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Data Analysis

Data was analyzed using IBM SPSS Statistics (Version 30). An Analysis of Variance was conducted in which the primary outcome variable was students' Anatomy and Physiology I (A&P) course GPA. Comparisons were made across three groups based on medical terminology course completion status: (1) students who did not take medical terminology prior to A&P, (2) students who completed the course at the same institution as A&P, and (3) students who transferred the course from another institution.

Additionally, the timing of medical terminology completion was assessed in semesters. A dichotomous variable was created to distinguish between students who took medical terminology within one year prior to enrolling in A&P and those who either did not take the course or completed it more than one year before.

Results

Of the 443 unique students who completed A&P from Fall 2020 until Fall of 2024, 332 students took medical terminology before A&P and 111 did not take medical terminology before A&P. Of those that took medical terminology before, 44 took the medical terminology course at another institution. Transferred medical terminology grades appear as a T on a transcript and, therefore, were not used in calculations of medical terminology grades. No students repeated the A&P course.

Of the 332 students who took medical terminology before A&P, 62 students took medical terminology during or within one to two semesters before A&P, and the rest took medical terminology more than two semesters before A&P, which is shown in Table 2. The A&P grade point average (GPA) of students who had taken medical terminology before was 3.71 and the A&P GPA of students who did not take medical terminology before A&P was 3.52. Figure 1 illustrates the A&P grade distributions of students who had not taken medical terminology, had taken medical terminology one year before, or more than one year before A&P.

Medical Terminology Course	Number of Students
Taken < 1 year before A&P	62
Taken > 1 year before A&P	270
Not taken medical terminology before A&P	111

Table 2. *Number of students in A&P from Fall 2020 to Fall 2024 classified according to prior exposure to a medical terminology course.*

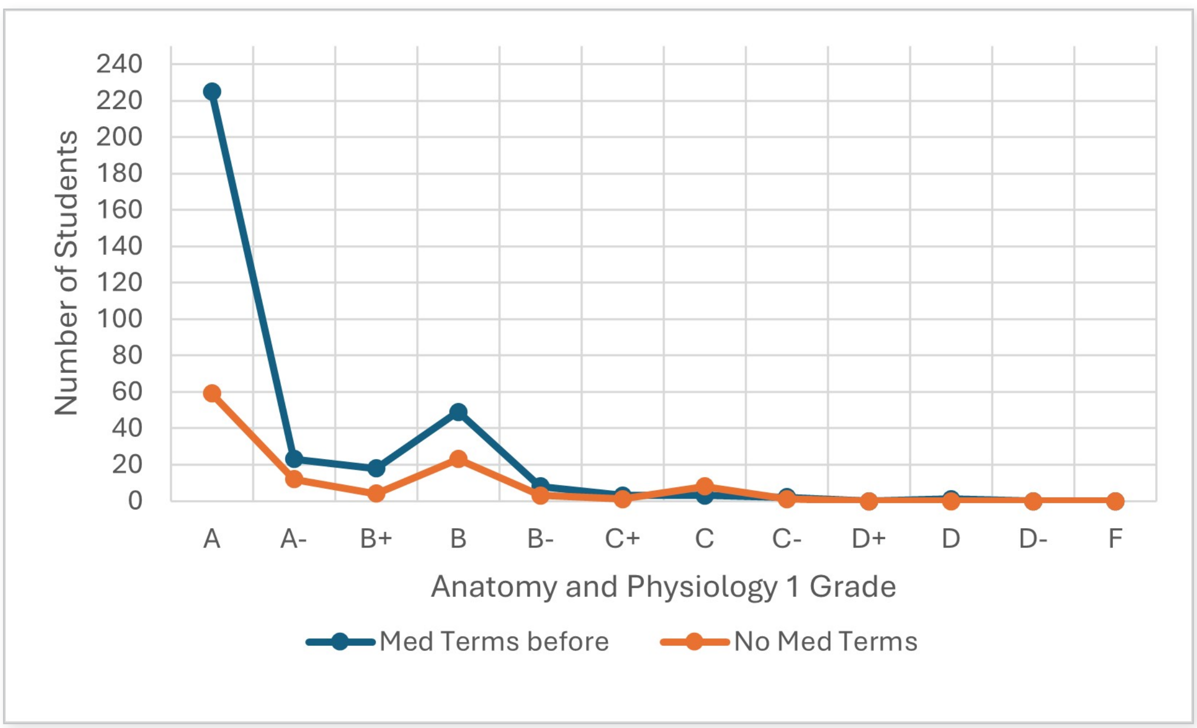

Figure 1. *Anatomy and physiology grade distribution of students who did or did not take medical terminology before A&P. Welch's ANOVA was conducted to account for the unequal variances and indicated that there was a statistically significant difference between the means (p = 0.02).*

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A Welch's analysis of variance (ANOVA) was conducted to examine differences in the GPA for A&P based on students' medical terminology course completion status prior to A&P 1 enrollment. Welch's ANOVA was employed to account for unequal variances across groups (Levene's Test for Equal Variances $p < 0.001$). The results indicated a statistically significant difference in the GPA for A&P among the groups ($F(2, 100.82) = 4.04$, $p = 0.02$).

Post hoc analyses using the Games–Howell procedure revealed that students who did not take medical terminology prior to A&P had statistically significant lower GPAs than both students who completed the course before A&P (mean difference = −0.22, $p = 0.019$, 95% CI [−0.41, −0.03]) and those who transferred the course (mean difference = −0.24, $p = 0.038$, 95% CI [−0.48, −0.01]). No significant difference in GPA was observed between students who took the course before A&P and those who transferred it from another institution ($p = 0.938$). Additionally, no statistically significant relationship was found between the time elapsed since completion of the medical terminology course and the GPA from A&P ($t(441) = 0.29$, $p = 0.77$).

To account for potential differences due to instructor, a General Linear Model (GLM) including both medical terminology course status and instructor was conducted. The effect of medical terminology remained significant for A&P I grades ($F(2, 437) = 5.51$, $p = 0.004$), and the interaction with instructor was not significant ($F = 0.107$, $p = 0.898$), indicating that the observed higher A&P I grades for students who completed or transferred medical terminology were consistent across instructors.

Discussion

The constructivist theory of knowledge suggests that prerequisite courses will provide a foundation to facilitate new knowledge (Bodner, 1986). In addition, content familiarity, provided by prerequisites, may also play a role in learning new concepts (Shaffer et al., 2016). Our study found a higher GPA between students who took medical terminology before enrolling in anatomy and physiology, supporting the notion that base knowledge benefits students' success in future courses. One of the major aims of prerequisites is to prepare students for success in challenging courses such as A&P (Sato et al., 2017).

Academics may recommend taking medical terminology before an A&P course; however, literature regarding the possible benefit to undergraduates has been limited. Most studies regarding this association have mainly concentrated on medical students (Cortés et al., 2024; Drury et al., 2002; Smith et al., 2007; Stephens & Moxham, 2018). The one study that used an undergraduate population showed a weak statistical relationship between comprehension of Latin and Greek root words, which is the basis for medical terminology, and anatomy grades (Pampush & Petto, 2011). Unlike the present study, Pampush and Petto (2011) tested students' knowledge of Latin and Greek using the Latin and Greek Aptitude Test (LGAT) and compared that score with their adjusted final grade in A&P. Several studies have shown the value of prerequisite courses in contributing to success in higher level STEM courses (Donovan & Wheland, 2019; Forgey et al., 2020; Harris et al., 2004; McCoy & Pierce, 2004). However, one study reported mixed results when comparing the influence that a prerequisite physiology lecture had on more advanced physiology courses (Shaffer et al., 2016). This discrepancy could be a result of the prerequisite physiology lecture being content-based instead of foundational. Although content sometimes needs to be included for context, the main role of a medical terminology course is to introduce students to anatomical etymologies. It is this terminology exposure that serves as a foundation for future success in A&P.

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Pampush and Petto (2011) found no association between knowledge of Latin and Greek anatomical terms and anatomy and physiology course performance in undergraduate students-based survey and quizzing compared to an actual medical terminology class and final grades in our study. This study reported that a medical terminology course was considered a confounding variable and did not show a significant effect on the LGAT score, along with the adjusted A&P course grade. In terms of content their assessed curriculum was focused more on understanding the roots of words and not specifically on the medical terms that students receive in a medical terminology course.

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This was an unexpected finding as one would assume that previous exposure to medical terminology should translate into increased knowledge of Latin and Greek anatomical terms.

Another question that this study addressed is whether the timing of the medical terminology course before A&P had a factor in the final A&P grade. Based on the premise behind the Ebbinghaus forgetting curve, one would expect that the longer the time lapses between medical terminology course completion and A&P course, the least effect on the A&P grade (Murre & Dros, 2015). However, this was not the case as there were no significant results found in our study. It did not matter if the student took the medical terminology course right before A&P or several semesters before A&P as there was still a positive association in obtaining higher GPA grades.

Although this study did show that a medical terminology course completion before A&P was beneficial, one must consider whether the student took some type of anatomy and physiology course before taking the A&P course at the university. Pampush and Petto (2011) showed no significant relationship between prior anatomy and physiology studies with undergraduate A&P grades. However, graduate students who did take anatomy and physiology previously did feel that it helped them succeed in graduate-level anatomy and physiology courses (Cortés et al., 2024; Robertson et al., 2020; Souza et al., 2024; Stephens & Moxham, 2016).

Beyond the aforementioned, two additional aspects warrant consideration. First, is the possible effect that the COVID-19 pandemic had on the Fall 2020 A&P 1 course.

Although the COVID19 pandemic affected many aspects of daily life and higher education, its impact on A&P instruction in Fall 2020 was minimized. Courses were conducted in person, with small class sizes, mandatory masking, and social distancing, allowing students to engage in face-to-face learning in a manner comparable to subsequent years. Class sizes are generally small each year, which likely mitigated potential disruptions and helped maintain instructional consistency. Second, students who transferred their medical terminology credits performed similarly to those who completed the course locally, further supporting the robustness of the observed results.

Conclusion

The results found in this study show the positive impact that medical terminology coursework has on A&P grades among undergraduate students. Because A&P may be a difficult course for students, any recommendation to help better prepare students for A&P is warranted. In addition, the timing of the medical terminology course did not matter, as it still showed a positive impact. This finding may support those institutions that have the prerequisite of medical terminology before A&P, and may result in other institutions reviewing their prerequisite courses for A&P. Prerequisite courses, such as medical terminology, aid students in giving them the proper tools to be successful in A&P.

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The History of BMI: The Body Mass Index and its Utility as a Health Indicator

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Abstract

The Body Mass Index (BMI) was conceptualized by mathematician Adolphe Quetelet in the 1830s, and it remains a prominent tool in the healthcare sector to assess an individual's physical health today. Doctors encourage patients to achieve or maintain a "normal" BMI, and individuals often use this measure to set weight-related health goals. With the development and growth of technology over the past two centuries, healthcare professionals and researchers have become increasingly aware of certain concerns raised by using BMI as a standalone indicator of individuals' health status. By examining its historical derivatives in context and analyzing its role in weight-centric health analyses, this paper will address BMI's origins, its intended applications, and the question of its utility in effectively evaluating an individual's overall health in the present day. The dangers of emphasizing weight loss over other health indicators through our current application of BMI must be assessed. BMI may incorrectly classify and categorize an individual's health, as it overlooks many factors such as body fat percentage, ethnicity, and sex. BMI can additionally play a significant role in eating disorder development. By identifying these issues and considering alternative methods for evaluating the health of an individual, this paper will argue against BMI as a standalone tool in modern healthcare and personal practices. https://doi.org/10.21692/haps.2025.025

Key words: Quetelet, body mass index, BMI, health, weight loss

Introduction

Adolphe Quetelet (1796-1874) was a Belgian astronomer, statistician, and sociologist, and was considered a trailblazer for his application of mathematical analysis to the study of human populations. He was the first to study the relationships between height (H) and weight (W) using data tables, and he determined that his index (W/H^2) was superior to the widely used ponderal index (W/H^3). Quetelet did not intend for his index to be applied to medical care. His aim was to make population-based conclusions that would describe an ideal beauty standard for human beings. Quetelet believed that a man who deviated the least from the "norm" was closest to being a "man of God's creation" (Grue & Heiberg, 2006). He excluded the growth spurts that occur during puberty and changes to the body after childbirth (Eknoyan, 2008). The Quetelet index was not based on health or medical fact, but on ideology that would later serve to fuel the eugenics movement. It informed the work of Francis Galton, who coined the term *eugenics* to describe "the science which deals with all influences that improve the inborn qualities of a race; also with those that develop them to the utmost advantage." (Galton, 1909, p. 35). Galton followed Quetelet's practice of applying the normal distribution and error law to human population studies. Both men used this practice to perpetuate their own beliefs about physical appearance ideals (Grue & Heiberg, 2006). While Quetelet did not create the index with eugenics in mind, its influence on Galton highlights its problematic origins and its goals to define a standard of beauty, not to assess health.

The term *Quetelet Index* remained in use until physiologist Ancel Keys renamed it *Body Mass Index* (BMI) in 1972. Keys's popularization of BMI ultimately gave the measure its place in our society as a primary health indicator in medical practices. Keys, like Quetelet, did not intend his study for medical use. Keys admitted that body density was a better assessment of body fat mass, but that the

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time-consuming nature of calculating body density made it unideal for surveys (Pray & Riskin, 2023). Keys's focus on BMI was concerned with the ease of its transferability to research compared to other methods that might have been more accurate. Keys himself admitted that BMI was not the most accurate measure of body fat, but rather the most efficient. He was identifying trends in adiposity and researching indices of obesity. His goal was to apply the index to population studies to make data easier to analyze, not to apply such research to the individual for medical assessment. Regardless of his original intentions, Keys's study sparked public use of BMI in people's lives and caught the attention of the U.S. National Institutes of Health (NIH) in 1985. The NIH's increased popularization of BMI encouraged doctor's offices and hospitals to implement the measure into their individual health assessments of patients.

While Quetelet's and Keys's work was significant, neither of these men was a medical professional. Keys noted that BMI was not intended as a general measure of adiposity when Quetelet first conceptualized it (Keys et al., 1972). Quetelet's research applied mainly to Anglo-Saxon populations (Eknoyan, 2008), raising questions about the appropriateness of applying it to other populations. Keys was among the skeptics; he stated in his study that averages for weight and height for a given age and sex in a particular population may be inaccurate to apply to other populations, or even to the same populations at another time (Keys et al., 1972). Keys's study itself must be viewed with some skepticism, however, because of its overall lack of diverse representation of ethnicities and its complete exclusion of women. The largest percentage of his subjects, too, were Anglo-Saxon, adding little diversity to Quetelet's original study.

Inadequacy of BMI as a Universal Index

A person's sex plays a significant role in assessment of weight and health, but neither Quetelet nor Keys included women in their studies. Women generally have lower BMIs than men, even though their fat mass in proportion to their weight is around 20% to 45% greater than that of men (Nuttall, 2015). BMI does not just misrepresent women; it misclassifies them. Physiological differences in women must also be considered when assessing one's health. Cardiac autonomic modulation, sex hormones, cytokines, and lipid and glucose metabolism also differ from women to men, affecting their respective disease risks (Pray & Riskin, 2023). Such differences should lead to alternative treatment and care. When BMI assesses men's and women's mortality risks, it does not acknowledge the nuances of their biology as it relates to their overall health.

Age is another important variable that must be considered along with BMI because of the ways body fat stores and height change over time. Fat stores increase while height decreases, but most studies only provide initial BMIs (Nuttall, 2015). The varying ages of the cohorts Keys studied thus compromise the applicability of his research.

Looking past the insufficient diversity in these studies, there is also a lack of acknowledgment of the nuances in body weight. BMI considers only body mass and height; it does not account for body fat percentage, muscle mass, or additional characteristics that contribute to overall weight and health. Individuals with significantly differing fat to muscle ratios will have the same BMI if their weight and height are equivalent. Epidemiological studies do not often acknowledge exercise level or nutrient intake. When these factors are controlled for, risk of disease related to BMI goes away or is significantly reduced (Pray & Riskin, 2023). Some additional attributes of health that BMI overlooks are family history of diabetes, hypertension, coronary heart disease, metabolic syndrome, dyslipidemias, and familial longevity and carcinoma (Nuttall, 2015). If a patient visits a doctor with a health concern and is overweight according to BMI, they may be told to treat the symptom with weight loss, when they really have another underlying health issue that weight loss will not address.

BMI is used to classify different categories of weight. One category is "pre-obese"— overweight but not yet obese. According to BMI, these individuals would be at higher risk of mortality than those with a BMI classified as "normal." This assumption can lead to increased insurance premiums for those with higher BMIs. Results from the European Prospective Investigation into Cancer and Nutrition (EPIC) observational study (Pischon et al., 2008), however, contradict these mortality risk claims. This study included 359,387 Europeans ranging in age from 25 to 70 years old. The lowest mortality risk was found in the 26.5 to 28 BMI range, categorized as "overweight". If this group has the lowest mortality risk, reliance only on BMI is clearly flawed.

On the other side of the bias, some patients may be turned away from treatment they need because their BMI does not match that of a typical patient with the same illness. This occurs frequently with patients who exhibit signs of eating disorders. An anorexia nervosa diagnosis, for example, calls for a patient to achieve a "significantly low body weight," defined as a BMI of 17 or lower (American Psychiatric Association, 2013). This may cause healthcare professionals to overlook other signs of the illness if a patient is engaging in disordered behaviors but is not yet underweight. A patient may be losing weight at an alarming rate yet not meet the criteria for an eating disorder. Individuals with bulimia nervosa are typically within average BMI range,

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which may cause the illness to go unnoticed until there is irreversible damage to the body. Over-reliance on the BMI system can harm those struggling with or recovering from eating disorders by centering weight rather than behavior.

Adverse Impact of Misapplying BMI

The use of BMI as the primary index of health can stigmatize individuals with larger bodies and encourage maladaptive behaviors such as dieting and excessive exercise. Such practices are bound to fail, creating an endless cycle of overcorrection and compensation. Efforts to control one's weight that are motivated by the pursuit of a "healthier" BMI often perpetuate body satisfaction, believing they are working with a "bad" body until they achieve a "good" BMI. Stigmatization can lead to hopelessness and feelings of inferiority. This can lead some people to restrict necessary nutrients from their diet to lower their BMI, but since they are depriving themselves to achieve a number on their bathroom scale, their intervention would likely result in weight-cycling. Their failure is then perceived as an issue of willpower rather than a natural bodily reaction to deprivation. A weight-centered health regimen is harmful because body dissatisfaction only increases weight-cycling, as it is shown to escalate behaviors such as binge eating (Bacon & Aphramor, 2011).

Overuse of BMI affects more than the well-being of adults. BMI screening is often used in schools to assess the health status of growing children. Quetelet did not include children in puberty, who must be assessed differently from adults who are finished growing. The use of BMI to assess children's health may incorrectly categorize them, as it was intended only for grown adults; this is because height, weight, bone mass, and body fat percentage change differently during developmental stages (Nihiser et al., 2007).

Parents whose children are classified as overweight in such BMI screenings may intervene in damaging ways, such as restricting their diets. Instilling a weight-centric view of health in children at such an impressionable point in their development can increase the likelihood that they engage in disordered behaviors. Tylka (2014) highlights this by emphasizing that children who are underfed by in efforts to decrease their BMI can suffer negative health effects and increased BMI in the long run. Additionally, children may harm themselves in an attempt to lower their weight or to feel better about their bodies. According to the 2005 Youth Risk Behavior Survey, roughly 1 in 6 (16.7%) of high school students in the United States used harmful weight control methods, including extended periods without food, weight loss supplements, laxatives, or self-induced vomiting (Centers for Disease Control and Prevention, 2006).

While BMI encourages weight control and focuses on external health cues, new initiatives are suggesting an approach that encourages behavior control and focuses on internal cues (Tylka et al., 2014). It may be more beneficial for individuals to pay attention to internal attributes of health such as hunger, fullness, mobility, and strength, rather than paying attention to external variables like weight and calories. Interventions should shift focus toward behaviors that are modifiable and beneficial to holistic health. Weight, in these new approaches to health assessment, is seen as a side effect of lifestyle changes, rather than the cause of certain health effects, because certain measures of health are completely independent of weight. Such lifestyle changes can reduce blood pressure and blood lipids without changing one's body weight or BMI. For instance, exercise can improve insulin sensitivity in individuals who gain weight (Bacon & Aphramor, 2011). These examples demonstrate how shifting the focus toward internal cues may encourage behavior modification that can lead to increased overall health.

Examples of such a shift in focus include intuitive eating and joyful movement or exercise, where individuals are in tune with their bodies. They eat and exercise in ways that make their bodies feel good, independent of the number on a bathroom scale. Intuitive eating skills are learnable, and they improve nutrient intake while decreasing eating disorder symptomatology (Bacon & Aphramor, 2011). The literature supports that when a weight-centric health approach is replaced with intuitive practices independent of weight, overall physical and mental health improve, weight stigmatization decreases, and self-esteem increases dramatically.

The Health at Every Size (HAES) Approach as an Emerging Alternative

Holistic approaches to health—perspectives which Bacon & Aphramor (2011) consider physical, emotional, social, occupational, intellectual, spiritual, and ecological aspects of health, benefit self-esteem and promote a less negative outlook toward one's own body, embracing engagement in healthy behaviors out of love for the body, and not out of hatred toward it. An increase in self-esteem encouraged by behavior-focused interventions increases motivation for overall health maintenance (Bacon & Aphramor, 2011). In other words, if people feel good about themselves, they are more inclined to partake in activities and practices that will benefit their health and help them lead longer lives.

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Health at Every Size (HAES) is a growing movement that focuses on this holistic health perspective. It aims to shift our focus from weight control to intuitive eating practices and an emphasis on one's overall health. It treats weight as a side effect of health (Bacon & Aphramor, 2011), allowing the individual to destigmatize the idea of a "bad," "unhealthy," or "inferior" body type. It teaches that health is achievable regardless of weight nuances that come with sex, ethnicity, and age. A common misconception about HAES is that its elimination of weight as the focus will lead to worsened health outcomes. Bacon and Aphramor (2011) have noted, "No randomized controlled HAES study has resulted in weight gain, and all studies that report on dietary quality or eating behavior indicate improvement or at least maintenance" (p. 7). The Health at Every Size approach shows us that behavioral factors influence an individual's health more than the factor of weight alone. While one's weight is important to consider when analyzing one's health, it should not be the standalone indicator of health. Health may become more attainable when weight is shifted from the center of focus.

Summary

Adolphe Quetelet did not intend to create a primary medical tool for assessing health. When Ancel Keys popularized the *Quetelet Index* and renamed it *Body Mass Index,* he intended to make it more accessible for research. Neither man was a medical professional nor wished to influence the health sector the way that BMI eventually did. BMI's limitations outweigh its benefits, as it fails to represent sex, ethnicity, and age diversely. It does not take muscle mass, body fat percentage, or other health nuances into account, and it fuels restrictive dieting, excessive exercise, and other disordered eating behaviors. BMI is a misleading tool for children who are still developing, and it encourages a fixation on external factors for adults. New initiatives such as intuitive eating, intuitive exercise, and the Health at Every Size movement are promising steps toward prioritizing holistic health over the number on the bathroom scale. By making students aware of the BMI metric's shortcomings, educators can promote more inclusive and holistic ways to view healthy body forms to future health-care workers.

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Adventures with Alternative Grading

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Abstract

Traditional grading practices can distract students from focusing on learning, especially in high-stakes courses like human anatomy and human physiology. This case study examined an alternative grading design in a fully online, asynchronous human physiology course at a rural community college in northern California. Twenty-two students participated in an accelerated summer course with a focus on community-building, flexible deadlines, metacognition, grading transparency, and growth-based assessment using multiple grading schemes. Qualitative data were collected through anonymous post-course surveys. Most students expressed positive perceptions of the alternative grading approach, reporting decreased stress and gratitude for the enhanced focus on feedback and learning. However, some students experienced anxiety about not always knowing their precise course standing, reflecting the ingrained role of grades as motivators. The use of multiple grading schemes benefited nearly all students, with 64% earning higher scores than they would have under traditional weighting. Although the intervention was time-intensive and difficult to scale, findings suggest that alternative grading practices, when combined with intentional feedback and community-building strategies, can foster student growth and confidence. https://doi.org/10.21692/haps.2025.026

Key words: alternative grading, inclusive pedagogy, online education, community college, multiple grading schemes

Introduction

In spring 2020, the COVID-19 pandemic caused schools around the world to emergency-pivot to remote delivery, forcing educators to grapple with big questions about topics like online learning, educational technology, equity, access, academic integrity, and both student and teacher workload. One conversation that was taking place long before the pivot but gained traction during this time centered on ungrading, a poorly defined pedagogical approach in which educators critically interrogate assumptions about, and impacts of, traditional grading practices (Blum 2020; Feldman, 2019; Sorensen-Unruh, 2020).

There is general consensus among educators that grades accurately indicate student achievement and learning (Brookhart, 2015). However, research casts doubt on the assumed intrinsic reliability of what a grade is and what it means because other factors, such as attendance, participation, and even punishment, can impact a student's grade (Brookhart et al., 2016; Feldman, 2019; Kohn, 2011; Schinske & Tanner, 2014). The external motivation and often high-stakes nature of grades have also been linked to increased likelihood of students engaging in academic dishonesty (Murdock & Anderman, 2006). This is a significant issue as increasing numbers of courses are being offered via online modalities (Amrane-Cooper et al., 2021; Barthel, 2016; Dendir & Maxwell, 2020; Dey, 2021).

Despite concerns associated with the reliability of traditional grading, there have been few substantial changes to the practice (Brookhart et al., 2016), especially in science, technology, engineering, and math (STEM) fields where grades are often associated with the indistinct notion of rigor, which is usually defined as a combination of the amount of time a student puts into a class (workload) and the

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difficulty of the required tasks (cognitive challenge) (Francis, 2018). While STEM faculty boast higher degrees of rigor, there can also be problematic retention rates for systematically marginalized students (Culver et al., 2021).

Most institutions of higher education require instructors to assign a final grade for each student enrolled in a course. However, the actual process of determining that grade is usually left to the instructor's discretion and is thus widely variable and potentially inequitable and unfair (Blum 2020; Feldman, 2019; Hammond, 2014). One of the most important reasons to consider an alternative grading practice is to identify strategies to facilitate the success of all students, a move that could possibly help reduce educational disparities amongst systematically marginalized students (Arif et al., 2021). There are many reasons systematically marginalized students experience barriers to success in traditional STEM classes, including unequal academic background, cultural barriers that impact communication between student and teacher, and a lack of experience and support navigating academic institutions (Dewsbury & Brame 2019; Estrada et al., 2016). In combination with other interventions that aim to increase active learning (Theobald et al., 2020) and students' academic self-efficacy (Bradley et al., 2017), alternative grading strategies could be an important aspect of equitizing retention and success (Arif et al., 2021, Hogan & Sathy, 2022).

Experimenting with non-traditional grading practices is not new, particularly in the humanities. Peter Elbow (1997) advocated rethinking strategies for assigning grades for writing assignments in his paper "Grading student writing: Making it simpler, fairer, clearer." Alfie Kohn (2011) wrote an iconic paper "The Case Against Grades" in which he argued that we've long known about problems with grading, including reducing curiosity and critical thinking, and incentivizing the easiest route through course materials.

STEM researchers are also talking about grading practices (Johnson, 2023). Jeff Schinske and Kimberly Tanner (2014) added to the literature with their paper "Teaching More by Grading Less (or Differently)," concluding that grading, as most of us think of it, is not only tedious and unpleasant work, but is also highly variable and subjective, even within a single institution. In 2017, anthropologist Susan Blum was featured in *Inside Higher Ed*, talking explicitly about "getting rid of grades." Blum later published (2020) a compilation of essays written by 13 educators from different backgrounds and experiences in her book *Ungrading: Why Rating Students Undermines Learning (and What to do Instead)*. In the introduction, she states, "This book is an effort to assemble some of the practices faculty have devised to question the apparent centrality of grades as an unchanging, unyielding fact of schooling (according to both teachers and students)."

As more educators examine potential inequities embedded within their grading practices, professional development opportunities and learning communities are emerging to discuss solutions. For example, a cursory internet/social media search conducted by the first author on February 19, 2023 for learning communities related to ungrading revealed 149 mentions of the #ungrading hashtag on (then) Twitter in seven days, an ungrading Discord hub followed by almost 600 people, an ungrading slack channel with over 1800 members, and almost 30 book clubs reading Susan Blum's book, *Ungrading*. The appearance of so many opportunities to collaboratively interrogate grading practices is also indicative of the myriad forms that alternative grading pedagogy can take. A January 30, 2023 post from the *Grading for Growth* blog by David Clark attempted to create a glossary for the many words used by educators exploring alternative grading pedagogies. This rather humorous post identified 10 types of alternative grading (featuring three different definitions just for the word "ungrading") and followed up with 13 more terms used to describe features often associated with alternative grading systems.

One of the most important aspects of implementing an alternative grading approach with an eye on equity is providing rich and meaningful feedback to students so they understand how to improve and grow. Such experiences may bolster students' sense of academic self-efficacy, such that they gain confidence in their ability to successfully tackle challenging course content in the future. "Warm, wise feedback" is a key pillar in the work of Michelle Pacansky-Brock and her team around humanizing online STEM classes (2022). Receiving feedback can be tricky for students (Payne et al., 2022) but can be made easier if they feel included in a supportive, safe, and vibrant learning community (Dewsbury, 2020). Transitioning the focus of a classroom from grades to learning can contribute to this community building (Guberman, 2021) and could potentially lessen students' anxieties related to academic performance and social evaluation in the classroom.

When the socially disruptive COVID-19 pandemic demanded that all educators pivot to online learning in spring 2020, we were presented with a rich opportunity to carefully interrogate our assumptions about grading, and experiment with more equitable grading practices. This paper represents the first author's culmination of that experimentation.

Rationale and research questions

The first author (W.R.) has been a community college biology instructor since 2009 and has always explored innovative pedagogies with the goal of maximizing student learning. The rest of this paper includes first-person testimony from the first author.

Following the spring, 2020 pivot to remote learning, I became particularly intrigued by the conversations about equity, grading, and student success and began to wonder if, by explicitly unlinking learning from traditional grading processes, I might help students increase academic self-

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efficacy and decrease anxiety in the classroom. I also wondered if helping students increase belief in their capacity might also make them more willing to engage with valuable active learning opportunities that have been shown to increase learning, particularly among minority groups who are often underrepresented in STEM (Ballen et al., 2017; Freeman et al., 2014).

In response to this line of inquiry, I developed an ungrading approach to a human physiology course I'd taught many times before. This approach allowed me to ask the following research question: What are students' perceptions and understanding of ungrading in this class? This case study was supported as part of the Refinement and Expansion of the Community College Anatomy and Physiology Education Research (RECAPER) project (2111119).

This paper explores how students experienced an alternatively graded summer session, fully online, asynchronous human physiology course in a rural community college in northern California. Primarily a commuter school, this college has a nursing program that works closely with the Biology Department. Although the course design was labeled "ungraded" throughout the entire term, this was a misleading description and "alternatively graded" is more appropriate. The project focused on examining student experiences in the class. Students were invited to complete pre- and post- course anonymous surveys, and they also submitted a course evaluation.

Methods

Context of the case study

Data collection for this project was approved by the Vice President of Instruction (in lieu of an Institutional Review Board) and informed consent was obtained from all participants.

Student population

The students participating in the research described in this paper enrolled in human physiology during an accelerated summer session in which all course material was covered in eight weeks instead of the standard 16 weeks. The course was fully online and asynchronous, including the laboratory component. The course was capped at 24 students; 22 students enrolled in the class. Two of the students were kinesiology majors and the rest were pre-healthcare. All students had previously taken three pre-requisite courses: non-majors general biology, introduction to chemistry, and human anatomy. Human physiology is usually the last course students take before applying to their professional programs or transferring to a four-year institution. At the time of data collection, 18 students successfully completed the requirements to pass the class.

Prior to the COVID-19 pandemic, human physiology was taught entirely face-to-face, primarily during regular 16-week semesters. The class was first taught fully online in fall 2020, and I taught four semesters in this modality before collecting data for this project.

Assumptions

Although the course was described as "ungraded," two main assumptions provided foundational context to the experiment:

1. Numbers (scores or grades) can communicate important information about student understanding and can thus provide direction for learning and teaching, especially in introductory STEM courses with a high content load.
2. At College of the Redwoods, all classes culminate in the assignment of a final course letter grade.

Students received numerical feedback on many assignments and scores were captured in the learning management system (LMS) gradebook. In this way, scores and numbers were used to provide students with feedback about their progress and the gradebook served as a convenient way to keep track of the work each student did in the course. However, the process by which scored assessments were used to determine the final course grade was unique.

About the course

"An inclusive classroom is one where all voices, regardless of background have equal opportunity to contribute to and shape the community dialogue." (Dewsbury, 2020).

This course was designed to create what Brian Dewsbury would call an inclusive classroom focused on trust and learning (2020). While the approach to grading was labeled "ungrading" to the students, in retrospect, this was a misleading description of the personalized, transparent, and interactive approach to course design, facilitation, and assignment of grades. Similar approaches have been described in the literature, especially Dewsbury's description of his "Deep Teaching" approach (2020).

Frequent and relational feedback, weekly check-ins, instructor accommodations, and personalized pep-talks formed an essential foundation for this experiment with different grading practices. The constant and patient attention paid to developing an authentic and inclusive classroom community enabled and empowered students to safely explore their experiences with learning and grades in this non-traditionally graded course.

All course activities, even exams, were considered formative assignments designed to provide opportunities for students to explore and expand their understanding of the course material. In all assignments, learning and growth were emphasized and rewarded. My role was that

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of a coach, helping students evaluate their understanding and ultimately reach their learning goals. There were seven different types of assignments in the class (Table 1).

New course content was delivered through video lectures covering the physiology of the human body. Each lecture was accompanied by several activities, including a quiz (scored for correctness) that could be taken an unlimited number of times and provided immediate and automated feedback, and an asynchronous discussion forum (scored for participation). Students were encouraged to collate their notes in an "External Brain," which was a compilation of hand-created notes that could be used on exams. Before every exam, students recorded a quick video (two minutes or less) to share the highlights of their External Brain organization. Completion was recorded in the LMS gradebook (1 point for credit/completion, 0 points for missing or incomplete).

Each week, students completed one or two lab activities that were also fully asynchronous. Students were encouraged to work together on the lab assignments (synchronously or asynchronously) and submitted a worksheet related to their activity (group or individual). They received feedback from their peers and were scored for completion.

Over the entire semester, students completed several assignments that explored how course content applied to various scenarios. This generally involved writing, research, and synthesis. Most students completed case study worksheets to meet this requirement, but they had the option of completing an independent project of their choosing.

All course work was designed to help students prepare for exams, which took place four times throughout the course. Exams were open for 3-5 days, although accommodations were made if students needed extra time. During each of the four exam periods, students had two exams: a timed multiple-choice exam and a timed written exam. The multiple-choice exam consisted of automatically scored questions pulled from question banks. Students were allowed (and encouraged) to take the multiple-choice exam two times while the exam was open. They were also encouraged to study between attempts. Their high score was recorded in the LMS gradebook. The written exam questions were also pulled from question banks, but all questions were manually scored by the instructor. Students had the option of receiving detailed and relational video feedback recorded during the actual grading process.

Assignment category	Lecture Activities	Quizzes	Labs	Check-ins	Case studies	External brain	Exams
Description	Asynchronous discussion forums requiring "meaningful participation"	Mostly multiple choice questions pulled from a bank of questions; can be taken infinite number of times	Asynchronous activities including kitchen labs, worksheets, computer simulations, and physiological data recording	Weekly video check-ins, text-type chats, or video conference conversations	Worksheet-type assignments asking students to explore clinical applications of the course content	Video documenting the compilation of all notes taken by the student in the lectures and labs leading up to each exam	One written exam (manually scored) with opt-in video FB and one multiple choice (autoscored) exam
Scoring	Complete or Incomplete	Automatically scored for accuracy	Complete or Incomplete	Complete or Incomplete	Complete or Incomplete	Complete or Incomplete	Manually and automatically scored for accuracy
Frequency	Four assignments per week	Four quizzes per week	Two labs per week	One check-in per week	One case study per two weeks	One EB check-in per two weeks	Two exams (MC & SA) every two weeks
% of total course grade	5%	5%	5%	5%	5%	5%	70%

Table 1. *There were seven types of assignments in the class, worth varying percentages of the final course grade.*

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At the beginning of each exam, students agreed to an honor code statement that clarified the rules of the exam. This honor code stated, "I promise that the work I do on this exam is my own. I will not consult with any other humans when completing this exam. I understand that I am allowed to use the resources I've created and collected in my External Brain, but I will not use the internet or my textbook to search for information or answers." Academic integrity was assured by checking the LMS quiz log after each exam. Exam scores were recorded in the LMS gradebook and served as the most significant pieces of evidence demonstrating the learning and knowledge gained in the course.

Finally, every week, students participated in a "check-in" assignment. Each check-in had several metacognitive question prompts to help students think about their progress in the class and ensure they were reflecting on their learning. While most of the check-ins had asynchronous submission options, a synchronous video chat meeting was required during Week 3 (after they received feedback on their first exam). A video chat meeting was offered in Week 8 to facilitate transparency during the assignment of final course grades. Table 2 illustrates a general timeline for all course assignments.

Interventions

There were four primary interventions administered in this class that accompanied the alternative grading strategies.

1. **High touch community.** A high touch community is created when students receive frequent tailored and human-centered support, helping them feel connected to the class as a whole, and invested in the complexities of the learning process. From the onset, the course was personalized, flexible, and focused on creating community (Dewsbery, 2020; Pacansky-Brock, 2020). All assignments (even exams) had "best by" dates rather than hard due dates, and while students were encouraged to keep up with the pacing of the course, there were no penalties for late work. Frequent contact was established through texts, email, video messaging, and video conferencing. Students were encouraged to work together on all assignments except exams.
2. **Relational video feedback.** While video feedback from the instructor was a consistent part of all class activities, students also had the option of receiving personal, individualized video feedback recorded while their written exams were graded. This strategy

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Lectures 1-3	Lectures 4-6	Lectures 7-9	Lectures 10-12	Lectures 13-15	Lectures 16-18	Lectures 19-22	Lecture 23
Labs 1-2	Labs 3-4	Labs 5-6	Labs 7-8	Labs 9-10	Lab 11	Labs 12-13	Lab 14
Quizzes 1-3	Quizzes 4-6	Quizzes 7-9	Quizzes 10-12	Quizzes 13-15	Quizzes 16-18	Quizzes 19-22	Quiz 23
Check-in 1: Getting to know you	Check-in 2: Are you ready for Exam 1?	Check-in 3: Meet up to discuss course progress	Check-in 4: Any changes in your prep for Exam 2?	Check-in 5: Halfway through!	Check-in 6: Ready for exam 3?	Check-in 7: This was a big week- did you notice?	Check-in 8: We're done! What do you want me to know?
	Case study 1		Case study 2		Case study 3		Case study 4
	External Brain 1		External Brain 2		External Brain 3		External Brain 4
	Exams 1		Exams 2		Exams 3		Exams 4
							Comprehensive final exam (optional)

Table 2. *All course assignments can be mapped onto the eight-week course schedule.*

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allowed students to see, in real time, how their work was assessed, and was coupled with constructive suggestions, positive affirmations, and important content-related clarifications. The video grading took about 10 minutes per student and the resulting video was attached to the exam in the LMS. Careful attention was paid to ensure video feedback was efficient, friendly, supportive, and direct (Pacansky-Brock et al., 2022; Payne et al., 2022; Schussler et al., 2021).

3. **Transparency.** Students participated in at least one reflective conference with the instructor to discuss their progress and growth in the course, and the grade they have earned so far. Scores in the LMS were updated frequently, so students had a way of tracking the work they'd completed. Students also participated in weekly asynchronous check-ins to support transparency and connection between instructor and student.

4. **Rewards for growth (multiple grading schemes).** Final course grades were assigned using a customized spreadsheet grade calculator that allowed the course grade breakdown to be individualized for each student. Students were given as much access to this spreadsheet as they wanted, and their grades were calculated based on five different grading schemes for exams, which made up 70% of the final course grade (Table 3). At any time, the highest grade reported in the spreadsheet was considered the student's course grade. This intervention was based on the successful implementation of flexible grading schemes described by Bailey et al. (2017). At any given moment, the grade reported in the LMS (considered the "normal" grade) was the lowest possible grade a student could earn. In addition to multiple grading schemes, all students had the opportunity to take a comprehensive final exam at the end of the course with the promise that their score on this exam could replace every single lower midterm exam score. In other words, if they learned the content eventually, there was redemption.

Exams: 70% of the final course grade	**Exam 1** *MC & SA*	**Exam 2** *MC & SA*	**Exam 3** *MC & SA*	**Exam 4** *MC & SA*	**FINAL** (opt) *MC*
SCHEME 1: All exams weighted equally	25.0%	25.0%	25.0%	25.0%	Optional final exam replaces ALL lower exam scores.
SCHEME 2: Steady improvement in all exams	20.0%	23.0%	27.0%	30.0%	
SCHEME 3: More drastic improvement in all exams	16.0%	24.0%	28.0%	32.0%	
SCHEME 4: Lots of improvement from first exam	10.0%	20.0%	30.0%	40.0%	
SCHEME 5: Lots of improvement from first exam, then steady	10.0%	30.0%	30.0%	30.0%	

Table 3. *There were five grading schemes for exams used in this case study. Student final course grades were calculated using all five schemes, then the highest grade was reported as the final course grade. In all grading schemes, the optional comprehensive final exam could replace all lower midterm exams.*

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	A	B	E	F	G	H	I	J	K	L	M	N	O	P	Q	T	U	W	X	Y	Z	AF	AG	AH	AI	AJ
1						SCHEME 1:	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	12.5%	100%											
2						SCHEME 2:	10.0%	10.0%	11.5%	11.5%	13.5%	13.5%	15.0%	15.0%	100%											
3						SCHEME 3:	8.0%	8.0%	12.0%	12.0%	14.0%	14.0%	16.0%	16.0%	100%											
4						SCHEME 4:	5.0%	5.0%	10.0%	10.0%	15.0%	15.0%	20.0%	20.0%	100%											
5						SCHEME 5:	5.0%	5.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	100%											
6							Exams									5.0%	5.0%	5.0%	5.0%	5.0%	5.0%					
7	*Spreadsheet*		*Canvas*				**1- MC**	**1- SA**	**2- MC**	**2- SA**	**3- MC**	**3- SA**	**4- MC**	**4- SA**	**Final**	**Lect**	**Quiz**	**Labs**	**Applic**	**Chekin**	**EB**	SCHEME 1	SCHEME 2	SCHEME 3	SCHEME 4	SCHEME 5
8	*82.65*	**B-**	*79.71*	*C+*	1	STUDENT A	**61**	**65**	70	**67**	**68**	**67**	83	86	69	98	97	100	100	100	100	73.3	74.0	74.3	**75.6**	74.1
9	*70.19*	**C**	*70.19*	*C*	2	STUDENT B	64	71	63	72	59	63	69	69	**48**	50	94	85	100	40	100	**66.8**	**66.8**	66.7	**66.8**	66.6
10	*97.27*	**A**	*95.61*	*A*	3	STUDENT C	98	91	95	96	94	95	95	100		100	100	100	75	100	100	97.5	97.6	97.7	**97.9**	97.7
11	*90.61*	**A-**	*86.48*	*B*	4	STUDENT D	**80**	**74**	**75**	88	90	**83**	87	**70**	84	93	100	100	100	100	100	86.7	86.8	86.9	87.0	**87.1**
12	*88.95*	**B+**	*85.57*	*B*	5	STUDENT E	**74**	**78**	**67**	97	**75**	84	**68**	89	79	100	100	100	100	100	100	83.4	83.5	83.7	83.8	**84.2**

Figure 1. *Snapshot of the spreadsheet grade calculator with data from five sample students.*

Spreadsheet grade calculator

One of the most complex parts of the grading process was the spreadsheet grade calculator.

Figure 1 captures the grading spreadsheet with data from five sample students (A-E). The top portion (rows 1–6) lists five grading schemes, each with different percentage weightings assigned to exams. Below, the main table (rows 8–12) presents student identifiers, exam scores (yellow), and final exam results (pink). Additional columns (orange) show performance in non-exam categories, each weighted at 5%. The rightmost columns calculate cumulative exam grades, depending on weighting scheme.

For example, Student A's final exam score (69) replaced five lower individual exam scores (bold). Across the five grading options, Scheme 4 (bold) returned the highest possible final grade among all weighting options. This student's overall course grade using the spreadsheet was 82.65% (B–), compared with 79.71% (C+) in Canvas.

Student B took the final exam, however, their score (48) was lower than every individual exam score, so no midterm exams were replaced, and the final did not impact this student's overall grade at all. Schemes 1, 2, and 4 returned the same possible final grade and their Canvas grade was the same as their spreadsheet grade.

Student C didn't take the final exam at all, and all grading schemes returned an A grade, though the spreadsheet reported a higher percentage (97%) than Canvas (95%).

Both students D and E earned their highest scores using Scheme 5, and both had 5 midterm scores replaced by their final exam scores. Student D performed better on the final exam and earned an A- according to the spreadsheet (compared to the B reported by Canvas). Student E earned a B+ according to the spreadsheet (compared to the B reported by Canvas).

Assigning final course grades

Final course grades were determined at the end of the course during a video conference with each student. Throughout the semester, students were encouraged to reflect on their learning and think about what constitutes "evidence" that learning had occurred. Because of the way the LMS gradebook can be used to collect course work, students ended up with a portfolio of evidence of their learning. This, and the spreadsheet grade calculator, allowed the instructor to witness to the student's learning experience, but the role of "judge" was transferred to the students. Exam scores were the most important piece of evidence for most students. In the final video conference, students used the evidence captured in the LMS combined with their own copy of the spreadsheet grade calculator to determine the grade they felt accurately reflected their learning in the course.

To support students with their metacognitive skills and help them be effective judges of their own learning, they participated in a midterm reflection conference with the instructor during week 3 (after their first exam). In this conference, students discussed the grade they felt they deserved using the data they'd generated so far in the course. The conference in week 3 provided an opportunity to calibrate their work, learn about the spreadsheet grade calculator, and gauge their progress in the class.

Student feedback

At the end of the course, students were invited to give feedback about their experience by answering open-ended questions that were made available via the LMS. Students answered these questions anonymously. This report presents the major themes identified in students' responses to the questions "Please provide any feedback about "ungrading" in the class. Did it impact your learning? Should it be done again? Are there any tweaks or improvements that could be made?"

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Students were also invited to complete an additional survey (via Qualtrics) at the beginning of the course and again at the end of the course where they were asked to rate their level of anxiety in response to participating in an ungraded course, and to rate the extent to which they felt that an ungrading approach contributed to their learning. Inferential statistics were not carried out due to the low number of respondents.

Thematic analysis of student feedback

Student comments were coded in a single round by two readers (W.R. and S.H.) who reviewed all comments and identified major recurrent themes and sub-themes. Both readers agreed to these themes, and no theoretical frameworks or codebooks were used. The readers then categorized all comments according to these themes and sub-themes. Both coders independently reached the same conclusions, so no disagreements needed to be resolved. Exemplative statements for each theme and sub-theme are provided in the results section.

Results

Student surveys

Nineteen students responded to the end-of-term free-response questions in the evaluation about "ungrading". Two overarching themes were identified in student responses: generally positive and generally negative. 89% (17/19) of students made generally positive comments about "ungrading" (Table 4). The two students who did not find the ungrading approach to be generally positive both commented on the confusing nature of the grading approach, one effectively capturing this by simply saying "I still don't know what upgrading *[sic]* means??" This sentiment (confusion) was shared by 32% of respondents (6/19) (Table 4). The other student expressed a less common but salient concern about the stressfulness of not being completely sure what their grade in the class was at any given moment, saying, "...not knowing 100% what my grade is is *[sic]* always really stressful for me because the grade is my biggest fear and the one thing I always try to make sure to do well on so it can be stressful at times not knowing 100% what it is."

Among the generally positive comments, we identified several sub-themes contributing to students' positive perceptions of ungrading. 32% (7/19) of respondents explicitly stated that "ungrading" was helpful for their learning (Table 4). One student captured this sentiment by writing, "I loved it I felt it was more of an accurate concept, it helped me focus on learning the material. I feel like sometimes I would rather study to understand material and get to the assignments later if I needed to study more. It worked better for me to be able to turn things in on my time (late) so I could study the material more." 26% (5/19) said it decreased stress (Table 4). For example, one student stated, "I really enjoyed the un-grading in this class I definitely think it should be done more. Personally grades make me nervous so I really think this un-grading aspect really made me learn more and not be so nervous about my grade." 16% (3/19) captured the nuanced way the class design focused on growth and progress, one student saying, "It positively impacted my learning by showing me my growth, which I appreciated" (Table 4).

Comment category	Generally positive about **Ungrading**	Found **Ungrading** helpful for learning	Thought **Ungrading** was confusing	Found that **Ungrading** decreased stress	Liked that **Ungrading** focused on growth	Found the uncertainty of **Ungrading** stressful	Thought **Ungrading** promoted compassion
Number of comments	17	7	6	5	3.5	1	1
Percent of students (n=19)	89%	37%	32%	26%	18%	5%	5%

Table 4. *Qualitative responses to anonymous student surveys were coded by two readers and seven sub-themes were identified.*

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Rewards for Growth (Multiple grading schemes)

Thirteen students took the optional final exam, and all but two were able to replace at least one lower midterm score. After inputting all student scores into the spreadsheet grade calculator, final course grades were calculated and then compared to the "normal" grading in the LMS gradebook. This "normal" grade used Schema 1 to calculate the letter grade but did not incorporate the final exam replacement. The spreadsheet automatically replaced all lower midterm scores with a higher final exam score and reported the highest grade of all options. 64% of the students earned a higher score, when their grades were calculated using multiple grading schemes, and for 27% of the students, the multiple grading scheme calculations actually resulted in at least one letter grade category higher than the traditional straight average.

Interestingly, only three of the five grading scheme options benefited students, with the majority (47%) earning their highest grade with scheme 4. The traditional weighting represented by scheme 1 was the second most popular, with 32% of students earning their highest score from that scheme. Scheme 5 was the least used, with 21% of the students earning their highest scores from this distribution (Table 5).

Exams: **70% of the final course grade**	**Exam 1** *MC & SA*	**Exam 2** *MC & SA*	**Exam 3** *MC & SA*	**Exam 4** *MC & SA*	**# of students whose highest final grade resulted from each option**	
SCHEME 1: All exams weighted equally	25.0%	25.0%	25.0%	25.0%	6	32%
SCHEME 2: Steady improvement in all exams	20.0%	23.0%	27.0%	30.0%	0	0%
SCHEME 3: More drastic improvement in all exams	16.0%	24.0%	28.0%	32.0%	0	0%
SCHEME 4: Lots of improvement from first exam	10.0%	20.0%	30.0%	40.0%	9	47%
SCHEME 5: Lots of improvement from first exam, then steady	10.0%	30.0%	30.0%	30.0%	4	21%

Table 5. *The highest course grade for each student was calculated using each of the five possible grading schemes.*

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Discussion

I am always striving to identify ways to improve student learning, and this case study provided a rich opportunity to deeply explore the dynamic role grading plays in learning. Overall, although many thought the concept was confusing, students were generally positive about the ungrading intervention. They thought it was helpful for their learning and especially appreciated the emphasis on growth.

Student observations generally matched my own. By the end of the experiment, it was very clear that the term ungrading was not a useful way to describe what I was doing in my class. I absolutely loved the constructive coaching (via relational feedback) I got to do because of the option for students to receive video feedback on their written exams. A valuable feature was also the focus on learning and growth, and the challenge of helping students shift their focus from grades to learning. Finaly, I appreciated the hopeful approach of redemption offered by the exam format and final grade assignment processes.

Despite the positive aspects of the experience, this was a very high-maintenance term, and it required a tremendous amount of time, organization, and emotional energy to ensure effective implementation. Providing individualized feedback, facilitating regular student reflections, and engaging in ongoing dialogue about learning goals demanded more attention than my usual grading workflow. With a small class of 22 students, this level of engagement was manageable, but barely. My experience illustrated how alternative grading practices can facilitate deeply relational and personalized student interaction, yet also underscored the significant labor involved in maintaining meaningful communication. Scaling this approach to a larger class could present logistical and pedagogical challenges unless additional structural supports were also in place, such as teaching assistants, peer review systems, or streamlined feedback tools.

Ultimately, there were four interventions facilitated throughout the course, and they all seemed to improve the student experience. The high touch community allowed students to be vulnerable and honest about their learning and focus on improvements. The video feedback they received while exams were graded provided honest guidance and detailed critique, delivered with a warm and positive affect that made the process constructive and palatable. The grading transparency demystified the process and allowed students to breathe more easily and focus on their learning. And finally, the unique use of multiple grading schemes rewarded students for their growth in a way that was accommodating to their own needs.

I will keep all four of these interventions in future classes. The primary adjustment I plan to make is clearly addressing the confusion associated with the ungrading terminology. In the future, communications about the alternative grading practices in these classes will be more informative.

Limitations

There are several notable concerns with this case study. First, the small sample size (n=22) constrained the ability to conduct inferential statistical analyses or generalize findings beyond this specific group. Second, although the primary planned intervention was "ungrading," that term proved to be conceptually ill-defined and didn't meaningfully reflect what ultimately unfolded in the course. Third, the course was scheduled during a shortened summer term (eight weeks instead of the standard 16). This intensified both instructional demands and student workload, possibly influencing engagement and outcomes. Finally, the course incorporated numerous overlapping interventions related to feedback, reflection, community-building, and assessment. The number of unique interventions in this course went far beyond the gradebook and teasing out the actual impact of each was nearly impossible.

Despite these limitations, this case offers meaningful insight into the lived complexities of reimagining assessment to improve student learning. As a small-scale case study, it provides a window into how grading practices might be critically examined, adapted, and humanized, even in the messy, variable conditions that characterize real-world teaching and learning.

About the Authors

Wendy Riggs, MS teaches general biology, human anatomy, and human physiology at College of the Redwoods. Riggs was the primary author and instructor of record for the class being studied. Suzanne Hood, PhD is an associate professor of psychology at Bishop's University. Hood coded student comments and contributed to project design and data analysis. Ron Gerrits, PhD teaches physiology and related courses at the Milwaukee School of Engineering and contributed substantially to the design and review of the project. Gerrits is a co-PI for the RECAPER project. Chasity O'Malley, PhD is an associate professor of medical education and physiology at Boonshoft School of Medicine at Wright State. She contributed substantially to the design and review of the project and is a co-PI for the RECAPER project.

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PERSPECTIVES ON TEACHING

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Educational Perspective: Using Case Studies to Teach Health Science Concepts to Nursing Students

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Abstract

Case-based learning in health sciences education bridges theoretical knowledge with real-world clinical practice. It is an instrumental pedagogical tool for enhancing teaching and learning in various science disciplines. By engaging students with realistic scenarios, case studies promote the application of concepts to complex clinical problems, enhance student engagement and critical thinking, and expand on skill acquisition beyond curricular outcomes. Recognizing its adaptability, we have successfully incorporated diverse case study approaches into biomedical chemistry and pharmacology disciplines. This scholarly work describes three learning activities: student-led case study presentations, online interactive case studies, and complex multi-stage case studies. Student-led presentations were either based on faculty pre-developed or student-generated cases, with emphasis on interactive components. Online interactive case scenarios involved a novel online resource generated by the research team, presenting realistic scenarios with integrated questions and explanatory feedback to strengthen students' biomedical chemistry knowledge. Lastly, complex multi-stage case studies comprehensively combined multiple nursing-related topics, which were analyzed collaboratively in large groups, fostering deeper understanding.

Based on our extensive experience spanning over 15 years, we share these insights to support educators in adopting these methods. Together, they underscore the pedagogical value of case-based learning, demonstrating its flexibility and effectiveness in enhancing student engagement, fostering critical thinking, and preparing learners for the complexities of clinical practice. https://doi.org/10.21692/haps.2025.027

Key words: health science education, case scenario, case study, educational research, case-based learning

Introduction

Case studies are long-established teaching tools that promote active learning by enhancing students' understanding of basic science concepts (Herreid, 1997). In health sciences education, the case-based learning approach can prepare students for clinical practice by linking theoretical knowledge to real-life practice (Brown et al., 2012; Thistlethwaite et al., 2012). Case studies provide students with realistic scenarios where they can apply their knowledge to solve clinical problems. This method helps students develop a deeper understanding of the material while fostering critical thinking and analytical skills. Current literature highlights several benefits of using case-based learning in health sciences education, such as encouraging the application of knowledge to new situations and enhancing learning retention and understanding (Bindelli et al., 2021; Brown et al., 2012; Thistlethwaite et al., 2012). Additionally, case studies are flexible and can be adapted for various educational levels and settings. This adaptability makes them valuable across disciplines and educational contexts. Furthermore, case-based learning has been linked to improvements in student performance (Brown et al., 2012; Latif, 2014; Thistlethwaite et al., 2012). By engaging with real-world scenarios, students quickly gain practical insight and a clear understanding of how theoretical knowledge is applied in real situations. The complexity of the case studies can be easily adjusted to meet student learning needs and education levels.

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The origins of case-based teaching in science and STEM education can be traced to the foundational work of Clyde Freeman Herreid and colleagues at the National Center for Case Study Teaching in Science (NCCSTS). Herreid (2011) provided a comprehensive framework classifying diverse case methods and demonstrated through empirical evidence that active learning using cases consistently enhances student engagement, conceptual retention, and collaboration. Later, Herreid and Schiller (2013) extended this work to the "flipped classroom," integrating case studies with pre-class multimedia learning to maximize active problem-solving during class time. These seminal contributions established the pedagogical foundation for much of the current case-based learning. The NCCSTS Case Collection created by the National Center for Case Study Teaching in Science contains over a thousand peer-reviewed case studies, many of them on the topic of anatomy, physiology, pathology, and nursing (https://www.nsta.org/case-studies).

Within the context of nursing, case scenarios have commonly been used in clinical skills education. As an educational tool for nursing skill acquisition, case scenarios have been shown to enhance nursing students' comprehension, increase engagement, and build professional skills (Kantar & Massouh, 2015; Liu et al., 2020; Raurell-Torreda et al., 2015). Additionally, case studies may develop critical thinking skills by improving the quality or ability for students to seek out new information, analyze data, generate decisions, integrate information, share information, and reflect on their skills (Görücü et al., 2025). Resultingly, it is anticipated that the benefits of this approach for nursing education will extend beyond nursing clinical skills courses. Overall, the integration of case scenarios into learning not only improves cognitive skills but also prepares students for professional and real-world challenges.

The interdisciplinary nature of case studies allows for a comprehensive learning experience, as they can be integrated into a wide range of health sciences courses to bring together complex anatomical, physiological, and pathological concepts. Biomedical chemistry is taught in the second year of undergraduate nursing school as a foundational course for medical-surgical nursing and pharmacology. Our narrative on the successful integration of a variety of clinically relevant case scenarios demonstrates how instructors can implement these beneficial and adaptive teaching tools into nursing education.

In this article we describe the three models of learning activities: student-led case study presentations, online interactive case studies, and complex multi-stage case studies. We share our experience with the three approaches and explain how they were used to enhance undergraduate nursing education, student learning, and critical thinking skills.

Student-led Case Study Presentations

The first method implementing case studies in teaching was to assign pre-developed cases to student groups after communicating relevant content in a lecture-based format (Mazzuchin, n.d.). To complete the activity, the class was divided into groups of three or four students. The complete clinical cases were given to the groups ahead of time and each group had a different case to present. The expectation was that after researching and learning the case, the students would develop a PowerPoint presentation incorporating the following components: a description of a clinical scenario, data about the disease pathology, such as signs and symptoms and laboratory values, and an interactive component to further solidify learning. To prepare their presentations, students were instructed to review the case with the class and to explain the specific anatomical and physiological processes behind the pathology. Please refer to Appendix 1 for an example of a pre-developed case study assignment.

To promote independent learning, the assignment was modified in 2021 to give students more flexibility within the cases. In this new assignment format, only the names of the diseases were provided, and students developed their cases independently. When describing this activity to students, the emphasis was placed on the interactive aspect of case-based learning. Interactive components were derived by the students and included examples such as creative storytelling, visual demonstrations, and student-generated quizzes.

An example of a student-derived case study includes a case about glucose-6-phosphate dehydrogenase enzyme deficiency, where the presenters first reviewed the normal enzyme function and its role in the protection of red blood cells against oxidative stress, then reviewed the specific signs and symptoms of the disease, followed by a skit where each student took on a pertinent role (doctor, nurse, laboratory technician, patient) to act a scenario. This example demonstrates that students were able to complete their presentations and convey key information from their assigned study to their peers successfully and interactively.

From our experience, students were more engaged and motivated during case discussions when they developed the scenario. Students enjoyed researching each case and often generated realistic clinical scenarios that were highly relevant to their nursing curriculum. Notably, when students were anonymously asked during the course evaluation surveys if they found this process helpful for their learning, over 95% answered yes, reflecting the benefits of this approach. This teaching activity proved to be especially useful during alternate course delivery and online learning during the COVID-19 pandemic period, as the student-led presentations made the virtual classes more interesting and enhanced student participation.

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It was apparent that students leading the case study presentations made the virtual classes more dynamic and engaging. Their active involvement increased participation and encouraged peer-to-peer learning. Many students reported that preparing and presenting the cases helped them understand the content more.

Online Interactive Case Scenarios

The second approach to implementing case studies in learning was by generating an online collection of clinical cases. Overall, 25 case scenarios were meticulously assembled, reviewed, and uploaded to our website (https://medchemlab.net/), "MedChemLab, Biomedical Chemistry and Lab Diagnostics," alongside key laboratory values and interactive quizzes (Table 1). The case studies are accessible to the students as an out-of-class, asynchronous, optional learning activity any time during the course. These case studies were developed to serve as self-guided learning tools to help the students assess their knowledge and understanding of a specific topic. More case studies will be added to the website as needed. Within our developed case scenarios, the emphasis is placed on independent learning and self-assessment.

All cases on the website start with a scenario relevant to nursing, a presentation of a specific health problem, and initial data about the patient's pathological condition. After completing the case, students are expected to interpret relevant laboratory values. To promote decision-making and facilitate a deeper understanding of the pathology, students are asked to answer several questions for each case. All case studies follow a quiz format and include different types of questions, such as multiple-choice, fill-in-the-blank, or matching. These questions guide them through their learning to further their understanding of specific organ functions and pathologies. Once completed, the students receive their quiz scores and can review their answers alongside detailed explanations for all questions. Resultingly, the quizzes serve as a self-assessment tool to promote learning and improve student preparedness not only for course-specific but for professional licensing exams as well. By providing the students access to these case scenarios, they can frequently enhance and assess their knowledge of the course material. See Appendix 1 for some examples of case scenarios used for the website and Appendix 2 for two full case scenarios.

Current List of Online Case Scenarios	
Enzymes, biomarkers, and their application to the diagnosis of disease	
Glucose-6-phosphate dehydrogenase deficiency	
Myocardial infarction	
Acute pancreatitis	
Endocrine system	
Hyperthyroidism	Acromegaly
Hypothyroidism	Central diabetes insipidus
Hyperparathyroidism	Nephrogenic diabetes insipidus
Conn's syndrome	Polycystic ovary syndrome (PCOS)
Addison's disease	Pheochromocytoma
Cushing disease	
Carbohydrate metabolism	
Diabetes mellitus - Type 2	
Diabetes mellitus - Hyperosmolar hyperglycemic state	
Diabetes mellitus - Diabetic ketoacidosis	
Diabetes mellitus – Hypoglycemia	
Liver and biliary tract	
Acute hepatitis A viral infection	Alcoholic liver cirrhosis
Acute hepatitis B viral (HBV) infection	Obstructive jaundice
Hepatic cirrhosis (after HBV infection)	Hepatocellular carcinoma
Primary biliary cholangitis	

Table 1. *Online interactive case scenarios available on MedChemLab*

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Complex Multi-Stage Case Study

The final learning activity involved complex multi-stage case studies, such as COVID-19 pneumonia and diabetic ketoacidosis, in the context of nursing pharmacology. The focus of this learning activity was to promote student collaboration and the application of knowledge to complex clinical cases. The comprehensive nature of these cases required students to utilize their knowledge of anatomy, physiology, pathology, and pharmacology. The case scenarios involved patients whose conditions evolved, thus requiring students to apply their pharmacology knowledge from numerous drug classes.

To facilitate this activity, pre-developed case scenarios were given as part of a group assignment. Each group consisted of 5-6 students. Within their groups, students were asked to review the provided signs and symptoms, laboratory test results, and physician orders to fill in charts and answer a series of short-answer questions. By providing students with basic questions that progressed to complex clinical problems, critical thinking skills were further developed. By working collaboratively, students were able to extract essential knowledge while working their way through a clinically relevant case scenario. This type of case study is well suited for an in-class group assignment or can be completed in a seminar setting. Please refer to Appendix 3 for an example of a complex multi-stage case study.

Discussion

Implementing case-based learning in the undergraduate nursing curriculum, as described in this study, revealed several pedagogical benefits. The use of case studies as an educational tool actively engages students, fostering deeper understanding and application of theoretical knowledge in realistic clinical scenarios (Bindelli et al., 2021; Kantar & Massouh, 2015; Latif, 2014; Liu et al., 2020; Raurell-Torreda et al., 2015; Thistlethwaite et al., 2012). By encouraging students to analyze real-world scenarios, this approach enhances critical thinking and problem-solving skills, which are essential for their future professional practice (Hong & Yu, 2017).

Based on our experience using case studies as teaching tools, we observed that its flexibility and adaptability improved student engagement. For over 10 years, we have successfully implemented case studies in various formats, including student presentations, website-based cases, and multi-stage group assignments. Each method had distinct advantages, contributing to the overall goal of enhancing students' engagement and learning outcomes. For instance, the case scenario presentations allowed students to take ownership of their learning by independently researching and developing their cases. This autonomy increased their motivation and led to more active class participation, particularly in the virtual learning environment, such as during the COVID-19 pandemic. Additionally, the online interactive cases enhance self-directed learning and self-assessment through the presence of immediate feedback and sufficient opportunities for students to evaluate their understanding of the material. This ability to practice seeking out new information, gathering conclusions, and reflecting on responses improved critical thinking skills.

The successful completion of the complex multi-stage case scenarios highlighted the collaborative aspect of case study-based learning. Students were required to work together to solve complex clinical cases and to promote teamwork and communication skills that are critical in the healthcare environment. This method also facilitated the integration of multiple disciplines, as students had to apply knowledge from anatomy, physiology, pathology, and pharmacology to arrive at comprehensive solutions. By combining complex information, students were able to practice the critical thinking skills essential for a career in nursing.

Despite significant strengths, challenges remain in optimizing case-based learning. One challenge is ensuring that all students participate equally in group activities, as those who participate less may miss learning opportunities. In our experience, two methods were the most encouraging for students to equally participate. The multi-stage case study assignment required all students in the group to work equally because all participants received the same grades. Additionally, when students were required to develop their own case study or completed the case study quizzes on their own, they reported being more interested in the material compared to when listening to a group presentation.

Another challenge is the need for continuous development and updating of case studies to keep them relevant to current clinical practices, updated guidelines, and advances in medical science (Herreid & Schiller, 2013). Additionally, by combining the online interactive case scenarios with classroom supports, students are well-positioned to fully understand a variety of complex concepts. Future work will focus on refining the use of case studies in diverse learning environments, particularly in large class settings where individual attention can be limited. Large lecture classes often pose obstacles like student isolation, reduced peer interaction, and instructor feedback challenges; resources from NCCSTS and allied studies recommend small-group breakout, peer-facilitation, and tiered instructional supports as mitigations (Herreid, 2006). Additionally, continued research into the impact of case-based learning and our interactive online resource on clinical performance would provide valuable insights into its effectiveness as a teaching strategy in nursing education.

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In conclusion, case-based learning offers a dynamic, interactive, and flexible approach to teaching health sciences-related concepts, with clear benefits for student engagement and the development of critical thinking skills. Overall, the adaptability of this pedagogical tool to diverse courses and complex learning needs helps prepare nursing students for the intricacies of clinical practice.

About the Authors

Zsuzsanna Keri is a registered nurse at Kingston Health Sciences Centre in Kingston, ON, Canada, specializing in critical care nursing, including medicine, trauma and neurology. She has a long interest in educational research. She is one of the main developers of the website by designing the online case study quizzes. Jordan Harry is a current Bachelor of Science in Nursing student at St. Lawrence College and holds an MSc degree in translational medicine from Queen's University, both in Kingston, ON, Canada. Jordan is a peer-mentor and tutor who is passionate about advancing approaches to health sciences education. Dr. Youssef Assar is a physician and educator. He is a professor in the Bachelor of Science in Nursing Program at St. Lawrence College. He developed a large set of case scenarios and always strives to innovate in teaching and learning. Dr. Hisham S. Elbatarny is a physician, researcher, author, and educator. He is currently a professor and tri-campus science lead at the BScN Program at St. Lawrence College and associate professor in the Department of Biomedical and Molecular Sciences at Queen's University. He teaches anatomy, physiology, biomedical chemistry, pharmacology, and pathophysiology. His current research focuses on pedagogical tools, such as using analogies and case scenarios to improve students' learning.

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Appendix 1. An Example of a Pre-developed Case Study pertaining to Glucose 6-Phosphate Dehydrogenase Deficiency

Patient: 24-year-old African American male

Clinical presentation: lower back pain, malaise, shortness of breath, intermittent fever, acute hemolysis, acute severe rhabdomyolysis, upper respiratory tract infection symptoms, and acute renal failure

The patient experienced no recent trauma, had no contact with an individual with an infectious disease, no medication use, or fava bean ingestion.

Vital signs on admission:

- Heart rate: 105 beats per minute
- Blood pressure: 154/66 mmHg
- Temperature: 36.8°C
- Respiration rate: 18 breaths per min
- Saturation of oxygen: 99%

During the hospital stay, the patient developed intermittent fever and shortness of breath, which required oxygen administration via nasal cannula

Diagnostic tests: complete blood count, tests to examine creatinine levels, creatine kinase levels, urea levels, bilirubin, glucose, urine toxicology, urine culture, blood culture, enzyme immunoassay, Coombs test, aspartate aminotransferase, alanine aminotransferase, respiratory virus film array, and CT of abdomen and pelvis.

Results:

-Patient's blood smear: contained blister cells
-Elevated levels of C reactive protein, ferritin
-Decreased albumin levels
-Positive enzyme assay for G6PD deficiency.

Diagnosis: G6PD deficiency

Treatment: IV fluids, antibiotics

The class activity developed by the student in this case was a class discussion about the common triggers of clinical symptoms and specific diagnostic tests.

1. *What situations or conditions can trigger the symptoms of G6PD deficiency? Explain the mechanism?*
2. *What specific diagnostic tests are available to diagnose G6PD deficiency?*
   Explain the role of spectrophotometry and the methemoglobin reduction test.

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Appendix 2. Examples of online case scenarios from the website

The explanations in Italics are only visible for the students after completing the quiz.

Obstructive jaundice (Case Study 006)

Linda is a 53-year-old lady with no history of any chronic diseases. She presents to the urgent care clinic because of pain in the right upper abdominal region. She reports that she had similar pain about two years ago. At that time, the pain occurred occasionally, especially after meals, but she did not pay any attention to it. However, it got severe last week but improved after taking pain medications and monitoring her diet. She has not taken any pain medication since last week. She also noticed that her urine was darker and tea-coloured yesterday. Her last bowel movement was two days ago.

On examination:

- Height: 172 cm, Weight: 75.3 Kg, BMI: 25.5
- Heart rate: 108/min, Respiratory rate: 28/min, Temperature: 37.0°C, O2 SAT: 98%
- Tender epigastric region on palpation, yellowish discoloration of the sclera and skin.

Question 1: What is the most likely cause of the yellowish discoloration of the sclera and skin?

A. Elevated serum carotene level
B. Low hemoglobin level
C. Elevated serum bilirubin level
D. Low serum carotene level
E. Elevated serum biliverdin level
F. Low bilirubin level
G. Polycythemia

Explanation: *The yellowish discoloration of the sclera and skin is called jaundice or icterus. It is due to hyperbilirubinemia. Elevated serum carotene level causes yellowish discoloration of the skin but not the sclera. Anemia, which is a low level of RBCs or hemoglobin level, causes pallor, while polycythemia causes plethoric ruddy skin colour due to high hemoglobin level.*

Linda's laboratory examination showed:

Blood analysis:

- CBC:
  - RBCs: 4.7 x 10^{12}/ L, Hemoglobin: 136 g/L, Hematocrit: 0.42,
  - MCV: 96 fL, MCH: 32 pg, RDW: 12.6%, Reticulocytes: 42 x 10^9/ L (3.5%), ESR: 10 mm/hour,
  - WBC: 6.6 x 10^9/l, (Neutrophils: 4.3 x 10^9/L, Lymphocytes: 2.9 x 10^9/L, Basophils: 0.08. x 10^9/L, Eosinophils: 0.33 x 10^9/L, Monocytes: 0.6 x 10^9/L),
  - Platelets: 234 x 10^9/L
- Na: 142 mmol/L, K: 4.6 mmol/L, Glucose: 5.9 mmol/L, BUN: 8.0 mmol/L, creatinine: 87.2 µmol/L, uric acid: 223 mmol/L
- Triglycerides: 2.6 mmol/L, Cholesterol total: 6.5 mmol/L, LDL: 4.2 mmol/L, HDL: 1.2 mmol/L,
- Total bilirubin: 256 µmol/L, Conjugated bilirubin: 250 µmol/L AST: 49 U/L, ALT: 68 U/L, ALP: 711 IU/L, GGT: 289 IU/L, 5'-NT: 63 IU/L, albumin: 40 g/L, LDH: 188 U/L
- INR: 1.0, Prothrombin time: 11 Sec
- Viral serology: HBsAg: -ve, HCV AB: -ve, HAV IgG: -ve

Urine analysis: colour: dark brown, pH: 6.4, specific gravity: 1018, osmolarity: 631 mOsm/L; glucose, nitrates, ketones: negative, bilirubin: +++, bile salts: +, urobilinogen: negative, WBCs and RBCs: 4 and 0/HPF, squamous epithelial cells: 1-2/HPF, casts, bacteria, yeast: negative.

Stool analysis: pale (clay-coloured)

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Question 2: **In Linda's case, hyperbilirubinemia is caused by the accumulation of conjugated bilirubin in the blood. What is the difference between conjugated and unconjugated bilirubin?**

A. Unconjugated bilirubin is excreted into the bile.

B. Unconjugated bilirubin can be excreted by the kidneys into the urine.

C. Conjugated bilirubin is lipid-soluble; therefore, it must be carried by albumin in the circulation.

D. Unlike unconjugated bilirubin, conjugated bilirubin is water-soluble and excreted into the bile.

Explanation: *Unconjugated bilirubin is conjugated with glucuronic acid to form conjugated bilirubin. Conjugated bilirubin is water soluble, can be excreted into the bile by the liver cells. Unconjugated bilirubin is lipid-soluble and is bound to albumin in the blood. Therefore, circulating bilirubin consists mostly of unconjugated bilirubin.*

Question 3: Which enzyme is responsible for forming conjugated bilirubin?

A. Glucuronyl transferase

B. Biliverdin reductase

C. Gamma-glutamyl-transferase

D. Alanine transaminase

Explanation: *The enzyme responsible for forming conjugated bilirubin is called glucuronyl transferase.*

Question 4: Have a look at the laboratory results again. **What type of jaundice are Linda's laboratory results showing? Explain.**

A. Obstructive

B. Hepatocellular

C. Hemolytic

D. Prehepatic

Explanation: *The elevated conjugated bilirubin, elevated ALP and GGT, darker urine with no urobilinogen, and the clay-colored stool are characteristics of obstructive jaundice. Note: the patient also has hypercholesterolemia, and bile salts are also present in the urine; both are common findings in cholestasis.*

Question 5: What is the correct sequence of bilirubin metabolism? Put the steps of bilirubin metabolism in the correct order.

1. Biliverdin is converted into bilirubin in the RES.
2. Conjugated bilirubin is secreted into the bile.
3. Heme is broken down into biliverdin and iron.
4. Glucuronyl transferase converts unconjugated bilirubin into conjugated bilirubin.
5. Urobilinogen and stercobilinogen are oxidized into urobilin and stercobilin, which are excreted in urine and stool.
6. Unconjugated bilirubin is transported to the liver by albumin.
7. Hemoglobin is released from damaged red blood cells.
8. Conjugated bilirubin is converted into urobilinogen and stercobilinogen by colon bacteria.
9. Hemoglobin is broken down into heme and globin.

   A. 7, 9, 3, 6, 2, 1, 5, 8, 4

   B. 6, 2, 7, 9, 3, 1, 4, 8, 5

   C. 7, 9, 3, 1, 6, 4, 2, 8, 5

   D. 3, 1, 7, 9, 6, 4, 2, 8, 5

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Question 6: Match the three types of jaundice with the underlying possible pathological conditions.

1. Pre-hepatic
2. Hepatic
3. Post-hepatic

A. Toxic hepatocellular damage
B. Gilbert's syndrome
C. Hemolytic anemia
D. Cholelithiasis
E. Gastric ulcer
F. Pernicious anemia
G. Viral hepatitis

Explanation: *The three types of jaundice are: pre-hepatic (hemolytic), hepatic (hepatocellular), and post-hepatic (obstructive), depending on the origin of hyperbilirubinemia. Pre-hepatic jaundice is caused by the overproduction of unconjugated bilirubin from damaged red blood cells. Hepatocellular jaundice results from decreased conjugation due to liver damage or decreased cellular uptake. Post-hepatic jaundice is caused by impaired bilirubin excretion or biliary obstruction.*

Answers 1C, 2D, 3A, 4A, 5C, 6: 1C, F, 2A, B, G, 3D.

Diabetes Insipidus (Case Study 003)

Mr. White is a 63-year-old male, who visited his family physician with a one-month history of increased urination which wakes him up several times at night and frequently drinking water. Four months prior to this visit, he was involved in a motor vehicle accident and admitted to the hospital in a post-concussion state due to head trauma. A week after, he completely recovered and was discharged. He had never smoked and is occasionally a social drinker. His family medical history is insignificant.

On examination:

- Height: 182 cm, Weight: 78 Kg, BMI: 23.5
- B/P: 124/70 mmHg, Heart rate: 96/min, Respiratory rate: 16/min, Temperature: 36.80C, O2SAT: 96%

Mr. White' s laboratory tests showed:

Blood analysis:

- CBC:
  - RBCs: 6.0 x 10^{12}/L, Hemoglobin: 150.5 g/L, Hematocrit: 0.60,
  - MCV: 89 fL, MCH: 31 pg, RDW: 12.0%, Reticulocytes: 1%, ESR: 11 mm/hour
  - WBC: 6.5 x 10^9/L, (Neutrophils: 3.1 x 10^9/L, Lymphocytes: 3.2 x 10^9/L, Basophils: 0.07 x 10^9/L, Eosinophils: 0.31 x 10^9/L, Monocytes: 0.7 x 10^9/L), Platelet counts: 206 x 10^9/L
- Na: 152 mmol/L, K: 5.0 mmol/L, Cl: 111 mmol/L, Ca (total): 2.4 mmol/L, Ca (ionized): 1.2 mmol/L, Glucose: 6.0 mmol/L, HbA1c: 5.7%, BUN: 8.9 mmol/L, Creatinine: 120.0 µmol/L, Uric acid: 320 mmol/L
- Triglycerides: 2.0 mmol/L, Cholesterol: 5.1 mmol/L, HDL: 1.0 mmol/L, LDL: 2.1 mmol/L
- Bilirubin: 16 mmol/L, Albumin: 38 g / L, AST: 22 U/35L, ALT: 34 U/L
- TSH: 1.2 µU/mL, Total T_4: 80.2 nmol/L, Free T_4: 11 pmol/L, Total T_3: 2.1 nmol/L, Free T_3: 5.0 pmol/L
- Serum cortisol (8 am): 327 nmol/L, Aldosterone (recumbent): 0.13 nmol/L, Renin activity: 1.3 ug/L/hr
- Plasma Arginine Vasopressin: 0.46 pmol/L
- Plasma osmolarity: 319 mOsmol/kg

Urinalysis:

- Color: clear watery, pH: 7.1, Specific gravity: 1002, Osmolarity: 112 mOsmol/kg; Glucose, Ketones, Albumin, Bilirubin: negative, WBCs and RBCs: 1 and 2/HPF, Epithelial cells, Casts, Bacteria, Yeast: negative

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Question 1: Which of the following statements is correct regarding urine osmolarity?

A. Urine osmolarity is an accurate measure of urine volume.
B. Specific gravity is more accurate measure than urine osmolarity.
C. Urine osmolarity depends on water intake and hydration status.
D. Urine osmolarity is usually equal to plasma osmolarity.

Question2: How can you interpret Mr. W.'s plasma and urine osmolarity?

A. The urine osmolarity is significantly low while the plasma osmolarity is high, which means that Mr. W. has a problem concentrating urine.
B. Plasma osmolarity is normal while urine osmolarity is low because Mr. W. drinks a lot of fluid.
C. Both are higher than normal, which reflects a more concentrated urine.
D. It cannot be interpreted without knowing Mr. W's daily fluid intake
E. Plasma osmolarity is low while urine osmolarity is high due to renal failure.

Explanation: *Low urine osmolarity with high plasma osmolarity indicates that the kidney cannot reabsorb water or concentrate urine which leads to loss of amount of water bigger than normal.*

Question 3: A water deprivation test was conducted. The following are readings of body weight, plasma osmolarity, and urine osmolarity prior to the test and 6 hours after cessation of fluid intake:

	Baseline Time	6 hours
Weight (kg)	78	76.3
Plasma osmolarity (mOsmol/kg)	319	325
Urine osmolarity (mOsmol/kg)	112	115

According to the test results, what is the most likely diagnosis of Mr. W's condition?

A. Diabetes mellitus
B. Diabetes insipidus
C. Psychogenic polydipsia
D. Hyperaldosteronism
E. Renal failure

Two micrograms of desmopressin (DDAVP) were given to the patient, and urine was collected for 4 hours. Urine osmolarity became 738 mmol/kg.

Question 4: This test result indicates that Mr. W. has cranial diabetes insipidus:

A. True
B. False

Explanation: *While water deprivation test did not significantly change the urine osmolarity, the urine became more concentrated and the osmolarity increased after desmopressin injection. This is indicative of cranial diabetes insipidus which is characterized by deficiency of ADH.*

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Question 5:

__________________________ is responsible for the reabsorption of water in the distal renal tubules and the collecting ducts and synthesized by the __________________________. (Fill in the blanks)

Explanation: *Antidiuretic hormone (ADH) is synthesized by the supraoptic nucleus of the hypothalamus. It is transported to the posterior lobe of the pituitary gland and released if the plasma volume or osmotic pressure drops. ADH is responsible for the forming of aquaporins in the distal convoluted tubules and the collecting ducts making them permeable for water reabsorption.*

Question 6: What are the potential complications of diabetes insipidus? (Select all that apply)

A. Dehydration
B. Confusion
C. Severe anemia
D. Seizures
E. Peripheral edema
F. Orthostatic hypotension
G. Congestive heart failure
H. Bradycardia

Explanation: *In central diabetes insipidus, the deficiency of ADH synthesis or secretion results in excessive water loss and hypernatremia. Most of the complications are the consequences of dehydration and the related electrolyte disturbances. Patients are at risk of orthostatic hypotension, tachycardia, loss of consciousness, confusion, seizures and in severe cases coma can develop. Hemoconcentration is also a complication due to dehydration.*

Answers: 1C, 2A, 3B, 4A, 5D, 6ABDF

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Appendix 3. Case Study Assignment

A 60-year-old female named Donna presents to the emergency department by ambulance with worsening dyspnea, cough, purulent sputum, and fatigue. Her assessment findings are presented below.

Neurological: Alert and oriented to person, place, and time. Some confusion and fatigue are present. Glasgow Coma Scale (GCS) of 14.

Cardiovascular: Heart rate regular, capillary refill <5 seconds, palpable peripheral pulses, absence of peripheral edema, no chest pain.

Integumentary: Skin is pale and cool to touch. Patients are slightly diaphoretic.

Respiratory: Decreased air entry to bases bilaterally, crackles in the right middle lobe, and increased work of breathing demonstrated by accessory muscle use.

Gastrointestinal/Genitourinary: Normal bowel sounds present in all four quadrants, abdomen soft and non-tender, patient is continent of urine.

Musculoskeletal: Patient can move all extremities equally against resistance.

Past medical history: Hypertension, type 1 diabetes, generalized anxiety disorder with panic attacks, stable angina, and STEMI one year ago. The patient currently weighs 140lbs and has a height of 5’2.

Vital signs: Heart rate 106, blood pressure 100/64, respiratory rate 30, oxygen saturation 88 on room air, temperature 38.1°C, 0/10 for pain, and glucose 18 mmol/L.

Medications:

Ramipril 10mg PO OD

Acetylsalicylic acid 162mg PO OD (2 baby aspirin)

Atorvastatin 20mg PO OD

Nitroglycerin 1 tablet SL PRN

Insulin Aspart 10 units TID SC

Insulin glargine 10 units SC OD

Lorazepam 2mg PO PRN

Citalopram 20mg PO OD

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Part 1: Current Medications (32 Marks)

A. Identify two indications for use of ramipril in this patient and explain the drug's mechanism of action. (4 marks)

B. Identify and explain the indication, mechanisms of action, and relevant adverse effects of the medications that the patient is taking for their generalized anxiety disorder with panic attacks. (8 marks)

C. Briefly discuss why type 1 diabetes and type 2 diabetes have different pharmacological treatments. Provide one example of a medication used for the management of type 1 diabetes and one medication used for the management of type 2 diabetes. For example, provide the drug's mechanism of action and relevant adverse effects. (8 marks)

D. Following a myocardial infarction (MI), patients are given long-term medications to prevent another MI and further complications. What cardioprotective medications is this patient currently taking? What are the mechanisms of action of these medications? (8 marks)

E. Discuss which class of medications is commonly used post-STEMI but are not typically used in patients with type 1 diabetes. Provide an example of a drug in this class. (4 marks)

Part 2: Acute Nursing Care (40 Marks)

Once the patient is in a room, the nurse places the patient on 2L of oxygen via nasal prongs, titrating the patient's oxygen to achieve an oxygen saturation of 92% or higher. The nurse receives an order to initiate an IV with 0.9% NaCl at 100cc/hr, obtain a sputum culture, blood work, and urine sample for a urinalysis. The patient will also go to imaging to receive a chest x-ray. Shortly after carrying out these orders, the nurse receives the following results:

Investigation	Value/Result
Sodium	134 mmol/L
Potassium	6.0 mmol/L
Chloride	99 mmol/L
Calcium	2.23 mmol/L
White blood cells	18 x 10^9/L
Red blood cells	5.0 x 10^{12}/L
Hemoglobin	160 g/L
Hematocrit	0.500
Glucose	18 mmol/L
Beta hydroxybutyrate	4 mmol/L
pH of venous blood	7.2
Bicarbonate (HCO_3)	14
$PaCO_2$	28
Urine	Positive for ketones and glucose
X-ray	Infiltrates in the right middle lobe of the lung

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Based on the physical assessment and these results, the patient is admitted to the hospital, and the nurse receives two new orders. The first order is to administer 500mg of cefazolin IV q6h. The second order is to initiate a continuous IV infusion of insulin regular at 4 units/hr as per the insulin infusion order set.

A. Based on the initial triage assessment and current assessment findings, what do you believe is happening to this patient? What is the likely cause? Explain the pathophysiology of this condition and discuss what assessment findings led you to this conclusion (12 marks).
B. Discuss one reason why a patient with type 1 diabetes may have hyperglycemia despite taking their normal scheduled doses of insulin (2 marks).
C. What is the indication for the IV insulin infusion and how will it help the patient? (2 marks)
D. There are medications that are used for the management of abnormal blood potassium levels. Fill out the table below to discuss the mechanism of action and important nursing considerations for the medications listed (10 marks).

	Medication Name	Mechanism of Action	Important Nursing Considerations
Hypokalemia	Potassium Chloride		
Hyperkalemia	Kayexalate		
	Insulin and D10W		
	Calcium gluconate		
	Sodium bicarbonate		

E. Identify the medication class of cefazolin. Explain the indication, mechanism of action, and common adverse effects of cefazolin (4 marks).
F. Hospitalized patients may experience periods of nausea, vomiting, constipation, or diarrhea. Below is a table of common medications used to treat these symptoms. Fill out the table to discuss the mechanism of action and adverse effects of these medications (10 marks).

Medication	Indication	Mechanism of Action
Ondansetron		
Metoclopramide		
PEG 3350		
Lactulose		
Loperamide		

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Part 3: Hospitalized Nursing Care (40 Marks)

A few days later, the patient's condition begins to decline. Her vital signs are heart rate 108, blood pressure 90/68, respiratory rate 33, oxygen saturation 79% on a non-rebreather. She is starting to show significant signs of respiratory distress. A COVID-19 swab was done on this patient, and it came back positive. The team decides to transfer the patient to the intensive care unit (ICU). Upon arrival at the ICU, the ICU staff plan to intubate the patient. Patients who are intubated and ventilated are at risk for many complications, so there are protocols in place to reduce certain risks. Such protocols include deep vein thrombosis (DVT) prophylaxis and peptic ulcer disease (PUD) prophylaxis.

A. Below is a chart of medications that may be used for patients who require intubation. Fill in the chart below to discuss the indications and mechanisms of actions for the listed medications (12 marks).

Medication	Indication(s)	Mechanism of Action
Rocuronium		
Succinylcholine		
Midazolam		
Propofol		
Ketamine		
Fentanyl		

B. Which medication(s) from the chart above would the nurse anticipate may be ordered to facilitate intubation and sedation for the patient? Why? (4 marks)

C. Dalteparin is commonly used to prevent venous thromboembolisms (VTEs) in patients. Discuss the mechanism of action, drug-drug interactions, common adverse effects, the antidote, and relevant monitoring (6 marks).

D. Discuss two different classes of medications and a specific medication in each class that is used to prevent PUD in patients who are mechanically ventilated. Explain the mechanisms of action, and common adverse effects (6 marks).

E. Patients in the ICU with severe infections sometimes develop systemic inflammatory response syndrome (SIRS) which can progress to sepsis. Patients that experience these conditions may require vasopressors to maintain adequate blood pressure to ensure adequate perfusion of their organs. Explain the mechanism of action and relevant adverse effects of norepinephrine and vasopressin. (6 marks)

F. Managing and preventing arrythmias may be another intervention for patients in the ICU. Identify and discuss a medication used to treat symptomatic bradycardia and a different medication used for the treatment of supraventricular tachycardia (SVT). Discuss the mechanism of action and relevant monitoring. (6 marks)

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Learners in Action: Kinesthetic Approaches to Learning in Anatomy and Physiology

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Abstract

Physiological phenomena occurring at the subcellular level can be difficult for novices to envision. Kinesthetic learning exercises intended to illustrate the events occurring during these processes may help students grasp such concepts. Here, the author describes three specific kinesthetic learning exercises developed to help clarify: (1) actions of enzymes in biochemical pathways, (2) the myriad events occurring during DNA replication, and (3) the effect of myelination on the speed at which an action potential is propagated down the length of an axon. In addition to potentially clarifying concepts, these exercises may be helpful in refreshing or refocusing student attention during the class period. The three kinesthetic learning exercises described here require little of the instructor in terms of time, materials, or preparation. However, modification may be warranted due to classroom constraints or other limitations. https://doi.org/10.21692/haps.2025.028

Key words: active learning, kinesthetic learning, biochemical pathways, DNA replication, saltatory propagation

Introduction

Coursework in human anatomy and physiology (A&P) is an indispensable component of education toward careers in the health professions. However, it also poses a major challenge to students seeking such careers. Anecdotally, success rates in undergraduate A&P courses, particularly those geared toward students seeking to enter nursing and allied professions, are low, with as few as half of students who enroll successfully completing those courses. In my own experience, approximately two-thirds of students who take A&P with me complete the course with a letter grade of 'C' or higher, which at my institution is prerequisite for enrolling in subsequent coursework. One major source of difficulty in A&P courses are concepts at the subcellular level of complexity. Events occurring at this level underlie the macroscopic functions observed at the levels of tissues, organs, and organ systems. However, functions at the molecular and cellular level can be difficult for students to visualize or imagine.

Kinesthetic approaches to learning have been shown to be helpful in alleviating difficulties in learning abstract concepts in undergraduate physics courses (Richards, 2019). Both my own experience, shared here, and data published by others (Breckler & Yu, 2011; Krull & Rholl, 2020; Sturges et al., 2009) suggest that kinesthetic learning approaches may be similarly helpful in the A&P classroom. Kinesthetic learning refers to the use of hands-on, physical activity to acquire information. It is one of three "VAK" learning styles, the others being visual and auditory learning (Li, 2016). While theories of learning *styles* are largely considered "debunked" (Furey, 2020) and have since been replaced by theories of learning *preferences,* the underlying concepts nonetheless remain useful in supporting student learning (Hernandez et al., 2020; Tanner & Allen, 2017). As a form of active learning, kinesthetic approaches can promote increased student engagement in the classroom (Mobley & Fisher, 2014), in part by serving to redirect and cultivate attention (Lang, 2020). Increasing student engagement is one of many approaches that can result in improved student learning. Kinesthetic approaches have shown some success among medical students (Breckler & Azzam, 2011; Hernandez et al., 2020). It stands to reason that trainees in other health professions would benefit similarly.

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In this manuscript, I describe specific kinesthetic learning exercises I have developed to help students understand (1) biochemical pathways and their regulation via end-product inhibition, (2) replication of DNA, with a focus on comparing actions occurring on the lagging strand *versus* the leading strand, and, (3) a comparison of continuous *versus* saltatory propagation of an action potential down an axon and how myelination speeds up action potential propagation. These exercises were developed in community college classrooms containing approximately 16-25 students and link to the HAPS Physiology Learning Objectives indicated in Table 1. However, with some ingenuity, all three may readily be adapted to classes of greater or smaller size at all types of postsecondary institutions.

Biochemical Pathways

Biochemical pathways consist of series of enzymatic reactions that convert one or more precursors, or substrates, into one or more end products, with the product of one enzyme within the pathway serving as the substrate for the next. These pathways are frequently regulated through end product inhibition, wherein the end product of a pathway allosterically inhibits an enzyme catalyzing a step occurring early within the pathway. Oftentimes, biochemical pathways are illustrated in textbooks depicting only one copy of each substrate and one copy of each enzyme, with one copy of each end product resulting.

Obviously, this is a vast oversimplification and not an accurate reflection of what actually occurs in the cell, where you have numerous copies of each substrate, enzyme, and end product all interacting within the cytosol. To model this, I have developed the following simple kinesthetic learning exercise that requires no more than several pieces of plain printer paper and the active participation of the students. (To save trees, old print discards may be used. The sheets of paper may be reserved for reuse in subsequent iterations of the lesson or course as long as they remain intact enough to be handled.)

Kinesthetic exercise	HAPS Physiology Learning Objectives (HAPS, 2023)
A biochemical pathway and its regulation via end-product inhibition	**EC.3.5:** Define and explain the relationships among *chemical reaction, reactant, substrate,* and *product.* **EC.5.6:** Explain the role of enzymes in biological reactions
Molecular events occurring during DNA replication	**EC.4.6:** Describe the building blocks of the 4 classes of biomolecules and explain how these building blocks combine to create complex molecules (e.g., amino acids linked through peptide bonds become peptides and proteins with primary, secondary, tertiary, and/or quaternary structure.
Action potential propagation along myelinated *versus* unmyelinated axons	**D.3.18:** Compare and contrast the conduction (propagation) of action potentials in myelinated versus unmyelinated axons and in small *versus* large diameter axons.

Table 1. *Relevant HAPS Physiology Learning Objectives*

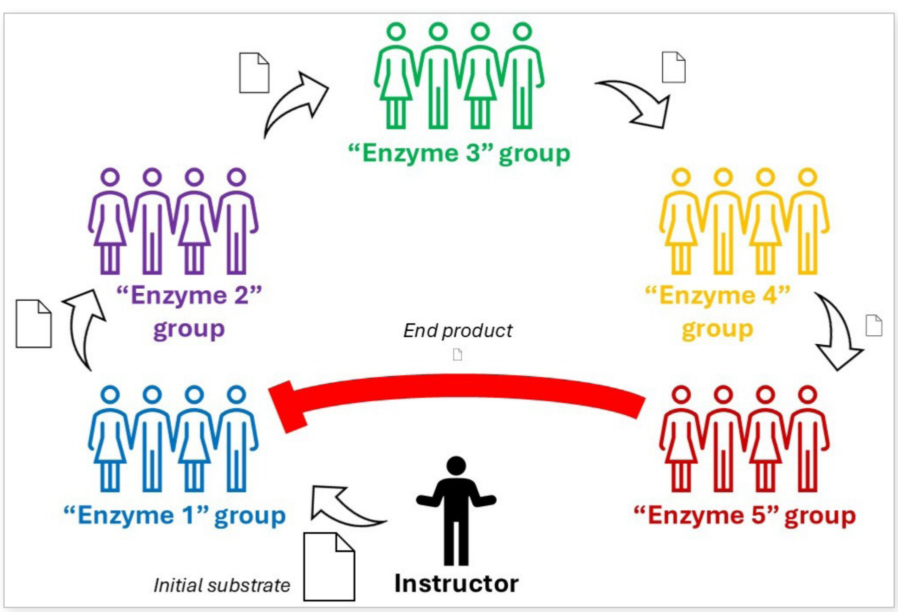

Figure 1. *A biochemical pathway and its regulation via end-product inhibition*

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1. The class is divided into three to five groups (Figure 1). Each group represents a particular enzyme within a biochemical pathway, with each group member representing a single copy of that enzyme. Each enzyme group is assigned a number, starting from 1, with the group assigned number one to serve as the first enzyme in the pathway.
2. The instructor presents members of the first enzyme group with an unfolded sheet of paper. This sheet of paper represents the initial substrate entering the biochemical pathway. To receive the substrate, the student must have their hands positioned together in front of them with the palms facing upward. This is important, as the hands represent the active site of the enzyme and their correct positioning represents the correct conformation for the active site to bind and act upon substrate. If the student's hands are not positioned correctly, the student is not to receive substrate until they are.
3. To model the conversion of substrate to product, the student folds the sheet of paper in half. They will then hand the resulting "product" to a member of the next enzyme group. As with the first enzyme group, each subsequent recipient must have their hands positioned together with the palms facing upwards to receive their "substrate." That student will then fold the paper in half again and present it to a member of the subsequent enzyme group, who will do the same until it reaches a member of the group representing the final enzyme in the pathway.
4. When a member of the final enzyme group receives the folded paper, they will fold it one final time and then present it to a member of the first enzyme group. Any member of the first enzyme group who is presented with this "end product" must, before accepting another copy of "substrate," accept the folded sheet of paper from the member of the final enzyme group and hold it against the side of their body with one elbow for approximately five seconds. This represents the allosteric binding of the end product to the enzyme, thus deactivating it. They will hold their other elbow similarly against the body during this time, and both hands will be held completely apart, representing the change in the conformation of the active site resulting from the allosteric binding of end product causing inhibition of the enzyme.
5. If a member of the first enzyme group has not been presented with "end product" by a member of the final enzyme group, they shall continue receiving substrate and converting it to product. Likewise, if they had been presented with end product and have completed the prescribed five-second pause described above, they shall hand the "end product" to the instructor for unfolding and reuse as initial substrate and then resume accepting substrate to convert to product. Members of all subsequent enzyme groups shall carry on similarly, receiving their substrate, converting it into product, and, in the case of the final enzyme group, presenting end product to members of the first enzyme group to inhibit them.
6. The exercise will continue as described until a moment is reached in which all members of the first enzyme group are under "end-product inhibition," representing the complete shutdown of the metabolic pathway within the cell by the presence of adequate end product. At this point, the instructor will declare that the pathway has been shut down through end-product inhibition, marking the end of the exercise.

DNA Replication

With the involvement of so many participants, including topoisomerases, helicases, primases, ligases, and polymerases, and so many things happening all at once, DNA replication can be likened to "The Waiters' Gallop" scene from the Broadway musical *Hello, Dolly!* Learning about this vital, elaborate process can be a dizzying experience for students who are encountering its details for the first time.

One particular point of confusion concerns the actions at the leading *versus* lagging strands during the replication process. While the actions of DNA polymerase and other key enzymes along the leading strand are fairly straightforward, those occurring along the lagging strand seem less so to some students. Static diagrams in textbooks and other resources can help, and videos or animations are even better. However, as we have seen with the previously described activity, a kinesthetic activity that places the student squarely into the perspective of one of the molecular participants of a process can engage students in ways that figures and animations cannot.

The following kinesthetic exercise was designed to illustrate for students the process of DNA replication, with particular emphasis on the comparative actions taking place at the leading *versus* lagging strands (Figure 2). As performed in my classes, this exercise required only three students to play active roles—two as DNA polymerase, one on the leading strand and the other on the lagging strand, and one as DNA helicase—with remaining students in the class portraying nucleotides within the respective template sequences. However, this activity can easily be adapted to include additional active roles, such as DNA ligase, as well as free nucleotides to be placed into sequence by the polymerases.

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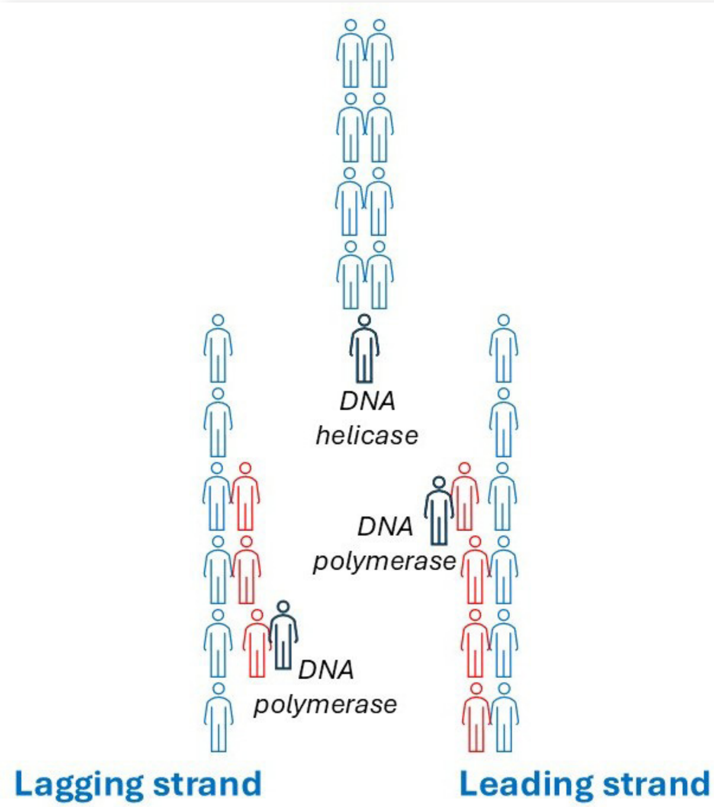

Figure 2. *Molecular events occurring during DNA replication*

1. An even number of students organize themselves into two lines facing each other. These students are portraying the nucleotides within the original double stranded DNA molecule to be copied. To model the hydrogen bonds between them, each student will grasp the hand of the student opposite them as though shaking hands. This handshake is held until the hydrogen bond is "broken" by DNA helicase or until otherwise instructed.
2. The student who is portraying the role of DNA helicase "breaks" each hydrogen bond by tapping the wrists of the two classmates portraying each base pair, whereupon the two students release their handshake. The two students will then take a step back to make room for DNA polymerase and, if applicable, the nucleotides inserted into each growing new strand by DNA polymerase.
3. If there are students playing the roles of free nucleotides to be placed by DNA polymerase, the student playing a DNA polymerase will direct each student to pair with a student from its template strand. If there are not enough students for there to be any playing nucleotides, then the placement of nucleotides will be symbolized by the student playing DNA polymerase shaking the hand of each student playing a nucleotide within the template strand, with that student keeping their hand held outward as though awaiting a handshake from the time they were separated from their original base pairing partner until DNA polymerase has "paired" them with a new nucleotide.
4. During this process, the student portraying the DNA polymerase on the leading strand will simply follow behind the student playing DNA helicase. However, since the lagging strand replicates in a discontinuous manner through generation of Okazaki fragments, the student portraying the DNA polymerase on the lagging strand will "place nucleotides" in a direction opposite that traveled by DNA helicase, thus requiring that player to backtrack to the new position of the helicase once a fragment has been completed. If there is a student playing the role of DNA ligase, they may symbolize their function by tapping the "nucleotides" at fragment ends on the shoulders, for example.

Continuous *versus* Saltatory Propagation of Action Potentials

The action potential (AP) is a key concept students must grasp to understand the functioning of muscular and nervous tissues. With respect to the latter, it is important to understand the speed at which an AP is propagated along the length of an axon. This is particularly salient with regard to the pathophysiology of demyelinating diseases. The kinesthetic learning exercise described in this section pertains to the propagation of an AP down the length of an axon, comparing its propagation along myelinated *versus* unmyelinated axons.

Two factors influence the speed at which an AP is propagated down an axon: axon diameter and the presence or absence of myelin (Wen & Chklovskii, 2010). All else being equal, an AP will be propagated more quickly along an axon of larger diameter, since a larger diameter axon poses lower resistance to the flow of ions within the lumen of the axon. This increase in speed of propagation occurs whether the axon is myelinated or not, but the addition of myelin has a synergistic effect on the speed of propagation such that an increase in axon diameter will result in a much greater increase in propagation speed along a myelinated axon than along an unmyelinated axon. Along an unmyelinated axon, the AP undergoes *continuous propagation,* where the AP is repeated at essentially all points along the length of the axon. This is in contrast to the *saltatory propagation* that occurs down the length of a myelinated axon. Here, the AP is repeated only at regions of bare axolemma between myelin sheaths called nodes of Ranvier, as the ion currents that underlie the events of the AP cannot occur on any portion of the axon that is covered by layer upon layer of lipid-rich myelin.

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In lecture, I often illustrate the difference in the speed of action potential propagation along myelinated *versus* unmyelinated axons by describing a hypothetical trip by passenger train, comparing how quickly the destination would be reached if the train stopped at all stations along the route, symbolizing continuous propagation along an unmyelinated axon, *versus* an express train that would stop only at a handful of major stations, symbolizing saltatory propagation along a myelinated axon. To further, and more vividly, demonstrate this concept, I have developed the following kinesthetic learning exercise in which students in the class model the propagation of an action potential (Figure 3). This exercise is simple, requiring no more than two groups of students and enough room for each to form a line, and requires very little time to perform. Both lines will conduct the exercise simultaneously. The instructor will describe the exercise to the students and tell them it is a race to see which line finishes first.

1. Students are divided into two groups, one representing a myelinated axon, the other an unmyelinated axon. The groups will be uneven in size, with a ratio of approximately two to four students in the unmyelinated axon group per individual in the myelinated axon group.
2. The two groups are lined up facing each other on opposite sides of the room. The distance covered between the first and last person in each line should be equal between the two groups, with individuals spaced evening within each line. Take care, though, that members of the myelinated axon group are no more than an arm's reach apart from each other, as with fewer members they will naturally be spaced more widely from each other than those in the unmyelinated axon group.
3. The first person in each line represents the axon hillock. When the instructor says, "Go!", that person will tap the next person in line on the shoulder. That person, upon being tapped on the shoulder but no earlier, will then tap the next person on the shoulder. That person will tap the next person, and so on, until reaching the last person in line.
4. The last person in line represents the axon terminal. When this person is tapped on the shoulder, they will shout, "Bingo!", symbolizing the release of neurotransmitter into the synaptic cleft.
5. In the spirit of replication and the scientific method, the instructor will have the students repeat the exercise a couple of times. Since the group myelinated axon group, having fewer members, should reliably finish first each time, this repetition will also further reinforce the concept for students.

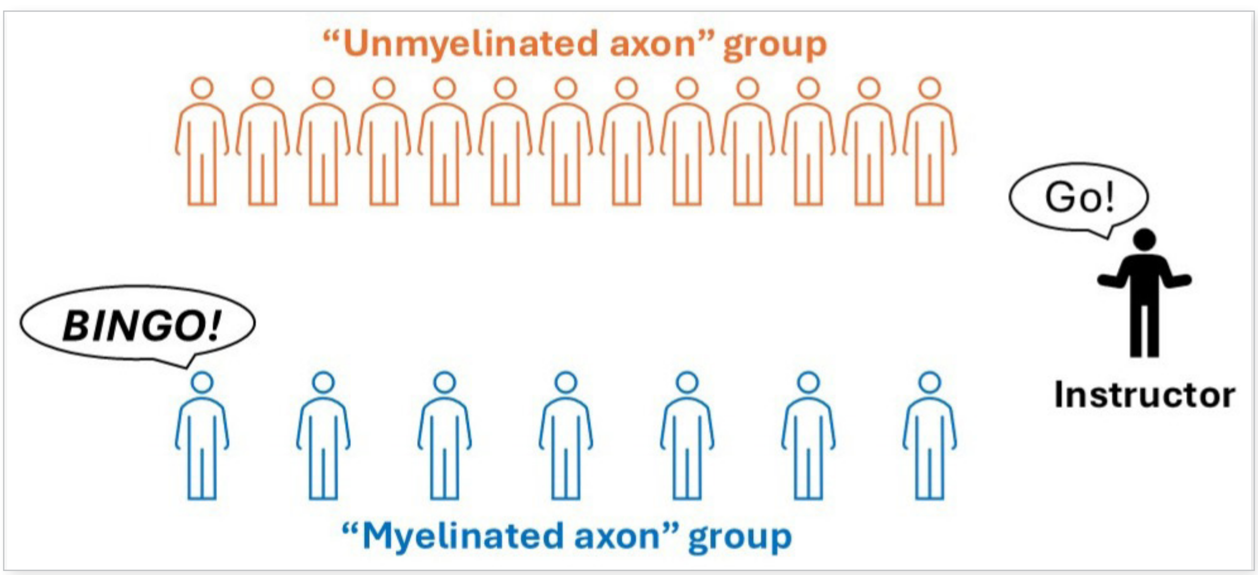

Figure 3. *Action potential propagation along myelinated versus unmyelinated axons*

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Discussion

Described above are three novel kinesthetic learning exercises on a few concepts relevant to physiology that, due to their molecular or microscopic nature, can be difficult for students to envision. Each exercise is simple, requiring little to no materials, props, or advance preparation. Additionally, each takes up minimal instructional time and can easily be adapted to classes of varying sizes. Since these exercises were implemented semi-spontaneously during the instructional period, no data were collected for assessment. However, students did appear to welcome the brief break from direct instruction and enjoyed the opportunity to get out of their seats, move around, and interact with their classmates.

The simplicity of these kinesthetic learning exercises makes them well suited for redirecting and refocusing student attention. In *Distracted,* James M. Lang (2020) characterized physical movement that relates to course content as one of several powerful ways to refresh and refocus student attention. Further, the introduction of brief periods of physical activity within the classroom can have beneficial effects on students with attention-deficit/hyperactivity disorder (ADHD) while posing no detriment to the learning of neurotypical students (Mulrine et al., 2008).

As with any classroom intervention, kinesthetic learning exercises such as those described here are not without limitations. The size of the classroom (Simamora et al., 2025), as well as the arrangement of its furniture, if not readily movable, may pose impediments to the movement of students during the exercise. Additionally, modifications may need to be made to facilitate the ability of students with limited mobility to fully participate in the exercises. Finally, rules or policies limiting movement or physical proximity of individuals within the classroom, as were implemented during the height of the COVID pandemic, may preclude the use of these exercises without substantial modification.

Conclusions

The three kinesthetic learning exercises described here were well received by students and required little in terms of materials or preparation to implement during instruction. In addition, they may help refresh and refocus student attention in the classroom and may pose particular benefit to students with ADHD.

About the Author

Justin A. Cobb, PhD, is a professor of biology at Lincoln Land Community College in Springfield, Illinois, where he teaches courses in human anatomy and physiology for students intending to enroll in programs in the health professions. He previously taught human anatomy and physiology, as well as general biology and microbiology, at John Wood Community College in Quincy, Illinois, where he developed much of the work presented here. Dr. Cobb received his PhD in neuroscience at the University of Mississippi Medical Center in Jackson, Mississippi. He also holds BS and MS degrees in biology from the University of Illinois Urbana-Champaign.

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PERSPECTIVES ON TEACHING

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Student Perceived Benefits of Interactive Learning Approaches used in an Undergraduate Pharmacology Course

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Abstract

Pharmacology, as a means to understand drug mechanisms related to pathophysiological states, is an important component of health-related undergraduate programs. Understanding disease treatments, specifically, the pharmacological mechanisms of action, aids students in mastering the related physiology and pathophysiology concepts. To enhance student engagement and promote learning of physiological drug mechanisms, active learning methods were implemented in a pharmacology course at a large land-grant university. The use of class activities (e.g., case studies, review questions, group concept discussions, exam-prep questions) was implemented with the goal of providing students with additional methods for understanding course material. Students were asked to assess their learning, and the benefits of the class activities, based on their retention and performance in summative assessments. Student perception of enhanced learning of pharmacological concepts, through participation in class activities, was supported by survey results collected at the end of the semester. Active learning strategies included case studies, review questions, concept discussions and exam-type questions. Results indicated that 89% of students found active learning beneficial for understanding and retaining course material. Students reported that the class activities supported their understanding of course concepts and enhanced their engagement with the class material. These findings highlight the value of integrating active learning, especially within-lecture activities, into traditionally lecture-based pharmacology courses to improve student learning outcomes. https://doi.org/10.21692/haps.2025.030

Key words: active learning, pharmacology, student learning, student engagement

Introduction

Limitations of Traditional Lecture-Based Pharmacology Instruction

Traditional pharmacology courses often rely heavily on didactic lectures, emphasizing rote memorization of drug names and mechanisms over developing higher-order skills such as critical thinking and application of concepts (Haidet et al., 2004; Kamal 2024). While this may support acquisition of knowledge and learning of factual information, this passive format, with little individual interaction with the instructor during class sessions, can lead to disengagement and poor long-term retention, particularly in large-enrollment or prerequisite courses in biomedical science programs (Plewka et al., 2023). This pedagogical model is not sufficient for preparing students for careers in the medical field, where integrative thinking is necessary (Oosthuizen et al., 2019; Plewka et al., 2023).

Benefits of Utilizing Active Learning in STEM

Active learning strategies, defined as approaches that involve student participation in activities promoting analysis, synthesis, and evaluation, have demonstrated positive effects on student performance, motivation, and concept understanding in science, technology, engineering, and mathematics (STEM) disciplines (Freeman et al., 2014; Grijpma et al., 2024). Empirical evidence across STEM disciplines have demonstrated that active learning improves conceptual understanding, increases student motivation, and improves academic performance (Mengesha et al., 2025). The usual techniques include team-based learning (TBL), case-based instruction (CBI), problem-based learning (PBL), flipped classrooms, and instructor-guided in-class exercises (Bucklin et al., 2021; Shrivastava et al., 2021).

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Pharmacology-Specific Benefits of Active Learning

In pharmacology, specifically, Kennedy (2019), Bucklin et al. (2021), and Shrivastava et al. (2021) have shown that incorporating case-based and team-based activities enhanced student engagement, problem-solving ability, and application of pharmacological concepts. Recent work by Alsaad (2024) further supports the integration of interactive class activities to promote deeper understanding and retention.

Moreover, the use of case studies helped to bridge the gap between theoretical knowledge and clinical application, which is particularly relevant for future healthcare professionals (Thistlethwaite et al., 2012). Review and exam-preparation questions, when aligned with learning outcomes, reinforce key concepts and allow for immediate formative feedback (Dobson, 2008). These approaches (e.g., low-stakes activities during class sessions) not only promote retention but also support inclusive and equitable learning, as they allow students to participate and process material at different cognitive levels (Haak et al., 2011).

The shift toward active learning in medical and biomedical education has gained increasing empirical support. Freeman et al. (2014) conducted a meta-analysis of 225 studies and found that students in active learning environments had higher examination scores and lower failure rates compared to traditional lecture-based settings. In pharmacology, specifically, active learning interventions, such as team-based learning and case-based instruction, have been shown to improve engagement and application of pharmacological principles (Kennedy, 2019). This is especially relevant as pharmacology can be daunting to many students, even those in science and health-related majors.

Restructuring and Current Gaps

Despite widespread evidence supporting active learning across disciplines, many pharmacology courses, especially at the undergraduate level, remain lecture-dominated. This persistence may be due to curricular inertia, faculty workload concerns, or perceived incompatibility with dense pharmacology content. Yet recent research consistently showed significant gains in exam performance and concept mastery in pharmacology when active learning was implemented (Alsaad 2024; Mengesha et al., 2025). Tobaiqy et al. (2025) found that students valued interactive teaching modalities, particularly case discussions and simulation-based learning, as tools for managing the cognitive load inherent in pharmacology.

Types of Active Learning

There are multiple methods for implementing active learning into a class session. These can include short questions interspersed throughout the lecture, brief activities promoting class discussion and peer-peer interaction, and short thinking activities aimed at enhancing critical evaluation skills, in addition to longer more involved activities. The use of activities in any form to promote participation and engagement can be a useful addition to class lectures and may be beneficial to student learning.

Active learning methods used during class sessions, such as concept questions, quick review prompts, exam-style application items, short mini-case studies, and rapid concept reviews, promote deeper processing and immediate retrieval practice without requiring prior student preparation. These strategies enhance engagement, support knowledge retention, and improve higher-order reasoning by prompting students to analyze, apply, and evaluate concepts in real-time (Freeman et al., 2014; Mengesha et al., 2025). Even brief, low-stakes activities embedded throughout a lecture have been shown to increase student performance and reduce achievement gaps by creating frequent opportunities for feedback, peer discussion, and concept clarification (Mengesha et al., 2025; Theobald et al., 2020).

Application to the Current Study

In response to these findings, the undergraduate pharmacology course described in this manuscript was restructured to de-emphasize memorization, move away from a lecture-only teaching method, and focus on interactive class activities that align with course goals. These included targeted problem-solving sessions, guided case discussions, small-group analyses of drug mechanisms, side effects, and molecular pathways, and student discussions relating to exam-preparation questions and concepts. This design sought to promote deep learning, enhance engagement, and help students develop the capacity to connect pharmacological knowledge to underlying physiological mechanisms. The present study reports on student perceptions of the efficacy of these strategies and evaluates their role in enhancing learning of complex pharmacological concepts.

Implementation of class activities has been shown to enhance student engagement, promote learning of difficult concepts, and provide a deeper understanding of the physiological mechanisms discussed in the lectures (Fasinu et al., 2024). While there are various studies that have examined the use of class activities in a pharmacology course, these are usually case-based learning, problem-based learning or team-based learning activities where students spend time outside of class preparing for the activities, to be worked on during class sessions, or activities that utilize a large portion of the lecture time (Kurshid et al., 2023; Thistlethwaite et al., 2012). This study instead focused on integrating various short activities throughout each lecture such that students worked on these during class time without any pre-class preparation required. The goal was to include these activities at the beginning of each lecture, within each lecture, and at the end of each lecture to support student participation and engagement during the entire class session.

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This study adds to a growing body of evidence supporting the integration of active learning in pharmacology education (Mengesha et al., 2025; Theobald et al., 2020).

This manuscript reports on student feedback and perceptions regarding the efficacy of these strategies in enhancing their learning of concepts in an undergraduate pharmacology course.

Methods

IRB Approval

This project was approved by the Institutional Review Board of Colorado State University (IRB #4703), and informed consent was obtained from all participants.

Study Purpose

The goal of this study was to revise a lecture-based pharmacology course by implementing in-class active learning approaches to enhance student engagement and promote student learning of course concepts. To assess this, students answered survey questions at the end of the semester relating to the following research questions.

1. Did the in-class active learning activities (case studies, review questions, exam-style concept questions) help you master course concepts?
2. Which activities (case studies, review questions, exam-style concept questions) did you find most beneficial for supporting learning in the course?

The hypotheses were: 1) the addition of active learning would be beneficial to student engagement and support their learning of pharmacological principles; and 2) the implementation of various types of active learning in the course, contained within the lecture time period (not requiring outside preparation), would enhance the student learning experience.

Students

The students were junior, senior, and graduate students taking a biomedical sciences pharmacology course. Of the 79 students in the course, there were 74 seniors, 2 juniors, and 3 MS students. Students in this course are usually planning to attend medical school, veterinary school, or to pursue another type of career in the medical field. This course has a prerequisite of one semester of biomedical sciences physiology, and one semester of biochemistry. However, the students in the course have varying backgrounds (engineering, biomedical engineering, biomedical sciences, biochemistry, exercise physiology, toxicology, etc.). Therefore, many different class activities were provided to support student success through multiple learning methods. The course was taught in the Spring semester, and the total student enrollment in the course was 79. Of those 79, 76 students (72 seniors, 1 junior, 3 MS students) completed the student survey administered at the end of the semester and gave consent for their survey responses to be used in this research project.

Course Description

The goal of this pharmacology course is to learn about the mechanisms of action for drugs used to treat pathophysiological conditions. In this course the students focus on the physiology and pathophysiology involved in specific diseases and how the different classes of drugs are used to treat the disorders investigated in the course. The course addresses the following areas:

1. Demonstrate an understanding of basic pharmacological principles, mechanism of action and classification of drugs.
2. Discuss the principles of receptor theory and identify different types of drug targets and their relevant use.
3. Compare the normal physiology in relation to the pathophysiology of common disorders.
4. Describe the different classes of drugs in relation to the organ systems they affect, and the diseases for which they are used therapeutically.
5. Explain the therapeutic effects, efficacies, side effects, toxicities and drug interactions of specific drugs.

Active Learning Approaches

Students met three times per week for 50 minutes per session. The class was lecture-only with no associated lab. The active learning activities were included within each class session, and interspersed throughout the lecture (e.g., short group review of lecture concept such as asking students to discuss the steps involved in a specific physiological pathway followed by a short lecture related to the organ system being discussed and the disorders that can occur in that system; inclusion of review questions for that organ system followed by a short lecture discussing the pharmacology involved in treatments of disorders in that organ system; quick review questions or exam-prep questions interspersed throughout the lecture; ending a lecture with summary questions or a short case study reviewing the material discussed in class). The activities and lectures varied by topic; however, all lectures followed this main outline.

Active learning elements were incorporated throughout the semester. The activities were included during every class session as well as multiple times throughout each lecture to promote student interaction and enhance learning. The class activities included: Concept Reviews, Quick Check Questions, Quick Review Questions, Critical Thinking Questions, Exam-Type Questions, and Case Study Questions. These included short, in-lecture case studies followed by discussion questions, collaborative peer-to-peer review questions, and interactive exam-style concept questions tied to systems physiology topics, such as the autonomic nervous system,

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skeletal muscle innervation, and cardiac electrophysiology. The case studies utilized in this course were short vignettes, describing a relevant disease, and correlating with the pathophysiology and pharmacological treatments discussed in the lectures. Examples of active learning implemented during the class sessions are shown in Table 1. Specific examples for each activity type are included in Appendix 1.

Survey

At the conclusion of the course, students were invited to participate in an anonymous survey evaluating their experience with active learning strategies. Including active learning in a course that is traditionally lecture-based and memorization-focused is a newer method for supporting student learning of pharmacological interventions for diseases. This was a new technique at the university for teaching the course, and the implementation of the class activities was assessed through student survey responses. Relevant survey questions are shown in Table 2.

Concept Reviews: These were usually asked at the beginning of class to encourage student discussions and to help students briefly review their prior knowledge of concepts related to the material being presented in class, or to briefly review past lecture material.
Quick Check Questions: These questions would be asked during class either at the beginning of the lecture as review for pervious lectures, or near the end of lecture, as a quick review of material presented in that lecture.
Quick Review Activities: These activities would be asked in class, and would be performed as group discussion, group work. The concepts would have been discussed and taught in previous lectures. They were usually presented to students at the beginning of a lecture to help with review of previous material.
Critical Thinking Questions: This type of activity would be used as a group discussion during lecture to encourage students to think about concepts and apply them to real-world situations. Answers would be provided following the group discussions to ensure students mastered the topics correctly.
Exam-Type Questions: These questions would be presented during lectures to encourage students to think about the concepts being taught and to provide examples of how questions would be asked on the exams.
Case Study Questions: These mini-case study questions would be used as short group activities for students to use as a method of relating pharmacological concepts to real-life scenarios. The mini-case studies and questions might be presented at the beginning of the lecture following discussion of the topic in a previous lecture, or at the end of a lecture where the topic was first discussed.

Table 1. *Examples of in-class activities.*

1. Did you find the in-class activities helpful?
2. If you found the activities helpful, which activities did you find most helpful?
3. If you did not find the activities helpful, please explain why.

Table 2. *Survey questions pertaining to active learning.*

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Student survey responses were categorized by perceived benefit and preferred activity type. Qualitative analysis of student responses (% of students who answered for each of the question choices) was used to report the distribution of responses. These percents were determined based on the number of students who answered the questions, with a specific response compared to all students who answered the survey question. These analyses are explained in detail in the Results section.

The survey questions were all qualitative and the student responses were short answer, free-response. Student responses were assigned a numerical value for calculation purposes (e.g., the number 3 was assigned for responses indicating that the activities were very helpful, the number 2 for somewhat helpful, the number 1 for not helpful, and 0 if there was no response), and the total number of responses for each category was calculated.

While the student population in this course was varied, with a variety of different majors, the majority of the students were seniors, with only 3 MS students and 2 juniors, thus, the level of college experience was similar among all students. Additionally, the responses to the survey questions were in relation to the course design, regarding, the implementation of lectures interspersed with a variety of class activities, and the responses were anonymous. Therefore, the student answers to the survey questions were pooled, as their backgrounds in relation to college course experience was similar.

Results

Of the 76 students who answered the survey questions, 89% (68 students) reported that the use of case studies and related questions, review questions, and exam-prep concept questions, were helpful in promoting their learning of the course material. Students reported that the use of case studies allowed them to examine the use of specific drugs in real-world situations. Additionally, students felt the review and exam-prep questions were helpful for assessing their knowledge during the lecture (did they remember information from past lectures, from the current lecture, and was their past knowledge sufficient). A detailed explanation of the student responses follows.

Perceived Activity Benefits

Of the 76 respondents, 64% (49 students) reported that the activities were very helpful. Furthermore, 25% (19 out of 76) of these students responded that the class activities were somewhat helpful. Of the 76 respondents, only 11% (8 students) reported that they did not find the activities helpful. Overall, 68 students (89%) of the 76 that responded, indicated that the class activities were beneficial for understanding and learning course material (very helpful and somewhat helpful). These survey results are depicted in Figure 1.

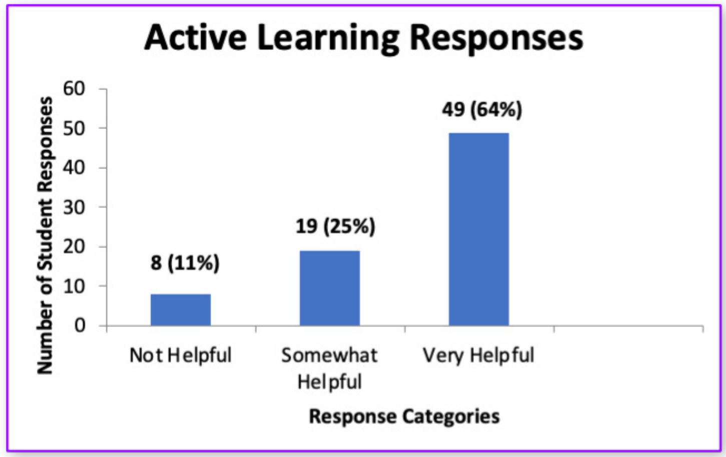

Figure 1: *Student survey responses regarding, the benefits of active learning in mastering course concepts. Survey choices were: very helpful, somewhat helpful, not helpful. 76 total survey responses.*

Student Preference of Activity Types

Evaluation of the survey results indicated that students preferred either both types of activities (questions and case studies) or one type of activity. In the survey responses, of the students who found the activities helpful, 56% (38 out of 68) reported that all types of activities were beneficial (case studies and review/exam-style class questions). In contrast, 23% (16 out of 68) preferred the class questions (review and exam-type questions), while 21% (14 out of 68) found the case studies, and associated questions, to be most relevant and beneficial. These results are shown in Figure 2.

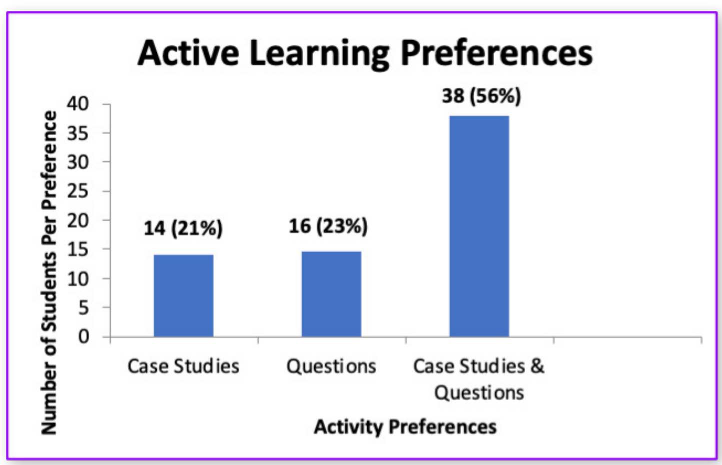

Figure 2: *Student survey responses indicating their activity preferences (case studies, review questions, case studies and questions). Out of 68 survey responses (those that answered yes to whether the activities were helpful).*

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Student Responses to Activities and Activity Types

Qualitative comments suggested that students thought the case studies enhanced their ability to apply drug knowledge to real-world clinical scenarios, while review questions helped reinforce material across multiple lectures and supported self-assessment during class. Table 3 shows selected positive responses to the different types of active learning implemented in the course, and the student views on which type of activities they found most beneficial. Table 4 shows selected negative responses to the types of active learning presented in the course and whether students found the activities helpful.

Discussion

The focus of this study was to re-design (from a lecture-only format) an undergraduate pharmacology course in a large land-grant university to include various types of active learning during lectures to promote retention and support student learning of the concepts discussed during the course. Students responded to survey questions related to these forms of active learning at the end of the semester. Of the 76 students who responded to the survey, the majority of the students responded positively to the active learning incorporated into the course. They reported that the class activities were helpful in their learning of course material. Of

Yes I really like case studies because it helps me make connections to real-world scenarios and apply the material which for me is the best way to retain information.
I thought the in-class activities were helpful. I think reviewing the material to check for retention and also seeing how the drugs and info applies in real life was helpful.
I really enjoyed the case studies and review questions. It helped me check my understanding of the material and bring everything I have just learned together.
I did find that the review questions during class were helpful because it made me stay on my toes during lectures and pay attention.
I do think the in-class activities are helpful to pinpoint what information I grasped versus what I needed to focus more on while studying.
Yes including the topics multiple times throughout the lecture was very useful and ensured understanding.
I really like the in-class activities because it really does make you take what you learned and summarize it really well. I used it a lot to make connections and just understand what I was supposed to learn from the lectures.
The reviews, questions, and case studies were helpful. They helped me test my retention of knowledge.
I found the in-class activities to be helpful. Especially because they highlighted weak points in my studying and or understanding of the material that I could then address after class. Further, I really enjoy "clinical-based" scenarios where we can apply the material to real-life situations and not just be given facts that we can't apply.

Table 3. *Representative positive survey responses pertaining to the in-class learning activities.*

The in-class activities were most helpful when they reviewed material we had covered in a previous lecture rather than the material we had just learned that lecture.
I did not find the in-class activities helpful. There is so much content covered in each lecture that I personally do not have time to study all of the material and be able to recall all of it during review questions, case studies, etc., during the next lecture.
Unfortunately, with the amount of material I didn't pay much attention to the case studies because at times they were only stressing me out more.
While I think they would've been helpful if they were given during a review session. When they were incorporated in class, I couldn't really answer them because there was so much information that I did not absorb yet.
I thought that the reviews and questions were very helpful, but the case studies ended up being a lot of unnecessary information. The questions were the most helpful to me because they helped me identify what I still needed to work on and gave me an idea of what kinds of questions would be on the exams
The review questions did not feel helpful because I had to use the extra time they gave me to try to catch up to the slide that the professor was on.

Table 4. *Representative negative survey responses pertaining to the in-class learning activities*

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the students who reported that the activities were helpful 56% felt that all activities (review and exam-type questions, and case study questions), were conducive to enhancing their learning and performance on exams. Interestingly, while some students preferred the case study questions, others found the review and exam-type questions to be more beneficial.

This study supports the implementation of active learning in a pharmacology course as a method for increasing student engagement and enhancing student learning and understanding of course concepts. The results suggest that in-class activities can be beneficial for encouraging student participation and promoting long-term retention of pharmacological concepts as self-reported by the students in the course. The overwhelmingly positive response from students highlights the potential for case-based learning, interactive questioning, and class review/exam-prep questions to enhance comprehension of complex physiological drug interactions.

The results of the survey indicated that the students valued both the practical application offered by case studies and the repetition and retrieval practice afforded by review and exam-style questions. These preferences reflect the diversity in learning approaches and underscore the importance of using a variety of pedagogical methods in order to reach all students effectively (Prince, 2004).

The finding that 11% of the students did not find the activities helpful may reflect a preference for traditional instruction, discomfort with peer interaction, or a need for more structured guidance in group tasks. In fact, some students reported that they did not work with their peers during the class sessions. Future research might explore these perspectives further and assess the relationship between learning outcomes and preferences for different activity types.

Some students felt that there was not enough time during class to appropriately answer questions (case studies and review-type questions). However, this was intentional, in that the activities were implemented to relieve the pressure of lecture-only type classes (as this course had been taught in past semesters), and to include different types of learning for students within a class session. This included quick reviews during lecture of material they were learning in the current lecture and reviews of material they had learned in past lectures. The goal was to help students identify areas that were unclear or required more study (Were they retaining concepts from past lectures? Were they following the current lecture enough to be able to answer quick review questions?). The activities were specifically created to address various aspects of pharmacology and to provide students with different methods for learning (reviews, quick recall, critical thinking questions, exam-type questions, short case studies). These activities allowed students to assess their knowledge (previous knowledge of physiology, knowledge from past lectures, in-the-moment knowledge from current lecture, application for case study and critical thinking questions, and exam-prep questions) in preparation for summative evaluation.

This study specifically addresses the implementation of active learning in a previously lecture-only undergraduate pharmacology course. The activities and survey questions were designed with this specific course in mind. However, as the literature shows (Alsaad, 2024; Bucklin et al., 2021), active learning can be beneficial for a variety of disciplines and can be especially helpful in courses such as pharmacology. The positive results based on the survey responses indicated that the majority of students in this study believed that the class activities supported their learning and improved their learning experience in this pharmacology course.

As this study was specific to my own course and the activities I designed to support student learning, I did not specifically compare these activities to those found in other courses. While case studies are often used in science courses such as pharmacology, students usually read these outside of class and potentially answer questions outside of class, or even during class time. I did not utilize the case studies in this manner, to avoid the need for pre-class preparation, other than the usual studying and learning involved with the course. My teaching method was to provide short lectures interspersed with a variety of class activities to support student engagement and enhance the student learning experience. Overall, these results support the continued and expanded use of active learning strategies in pharmacology education, particularly in settings where student engagement and long-term retention are priorities.

Limitations

The student survey data did not include questions relating to student demographics, exam grades, or overall course grades. In future studies, these questions will be included in the surveys and analyses, to strengthen the study results and provide avenues for further investigation and correlations. This study did not correlate exam scores with active learning preferences. However, this would be an interesting aspect to investigate in future courses.

Conclusion

Active learning strategies, including case studies and interactive questions, supported student engagement via student reporting, and enhanced learning (as evidenced by student responses to a class survey) in an undergraduate pharmacology course. Most students in the course reported that the class activities were beneficial in supporting

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their learning of course concepts. The data suggest that integrating these methods (e.g., using case studies and promoting student discussion of in-depth questions) into lecture-heavy STEM courses may be an effective way to deepen understanding and promote application of complex biomedical concepts (Alsaad et al., 2024; Plewka et al., 2023). The use of class activities provides a revised technique for promoting student engagement and participation in an undergraduate pharmacology course and suggests these alternative learning methods are beneficial to student learning of pharmacology (Kurshid et al., 2023). Thus, the use of active learning within, and throughout, class lectures can be beneficial for students, especially in courses that are usually lecture-heavy such as pharmacology.

About the Author

Dr. Kimberly Jeckel is an assistant professor in the Department of Biomedical Sciences at Colorado State University. She teaches biology, physiology, pharmacology, and pathophysiology courses. Her scholarly activities include implementation of innovative teaching methods designed to improve student success.

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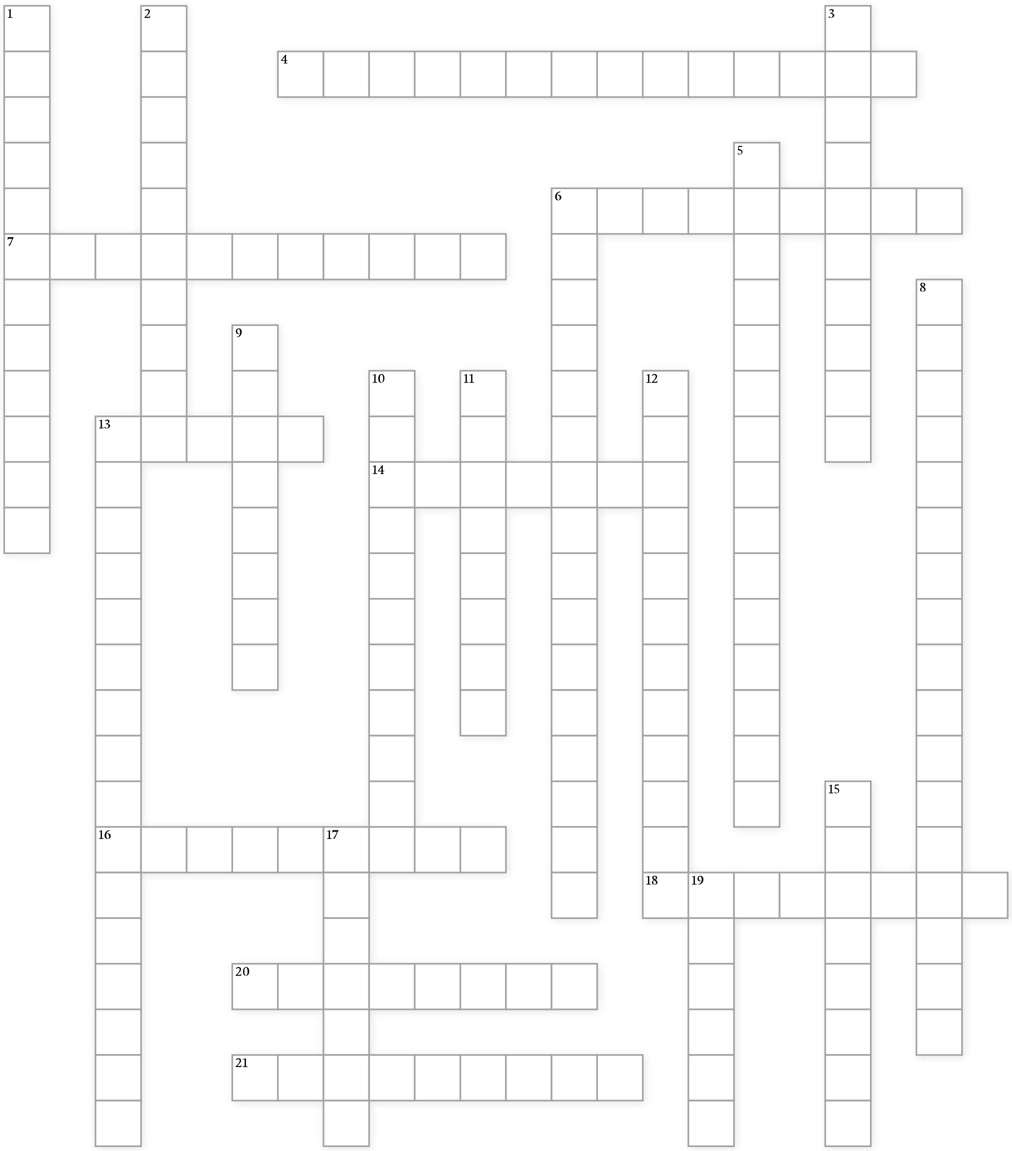
HAPS Educator Crossword 6: Neuroanatomy

(For an online version CLICK HERE.)



DOWN

1. Brain area composed of the thalamus, hypothalamus, and epithalamus
2. Mapping of a body area to a specific region in the brain
3. The gray ……………………. connects the left and right wings of gray matter in the spinal cord
5. The cerebellum consists of the anterior, posterior, and ……………….. lobes
6. Midbrain nucleus that has a high content of melanin (2 separate words)
8. This cranial nerve handles sensory information pertaining to hearing and balance
9. The cerebral …………………….. connects the third and fourth ventricles
10. Region of the brain involved in the transfer of information to long term memory
11. The vestibule of the inner ear contains the saccule and the ………………..
12. Area of the retina with a high concentration of cones for visual acuity (2 separate words)
13. Cranial nerve involved in swallowing and our gag reflex
15. Spinal nerve that is part of the sacral plexus and allows for voluntary control of urination
17. The lentiform nucleus consists of the ………….. and the globus pallidus
19. Singular of meninges

ACROSS

4. Term that indicates that each cerebral hemisphere has some abilities that are slightly different from those of the opposite hemisphere
6. …………………….. cells are supporting cells that surround neural cell bodies in ganglia
7. Connective tissue wrapping around a single nerve fiber
13. The precentral ………………… is the primary motor cortex
14. Spinal nerve that targets the diaphragm and is essential for breathing
16. Visual pigment found in rods and cones
18. Region of the limbic system associated with the emotions of anger and fear
20. Gateway to the cerebral cortex
21. Neural supporting cells that line the ventricles of the brain

CLICK HERE for Answer Key

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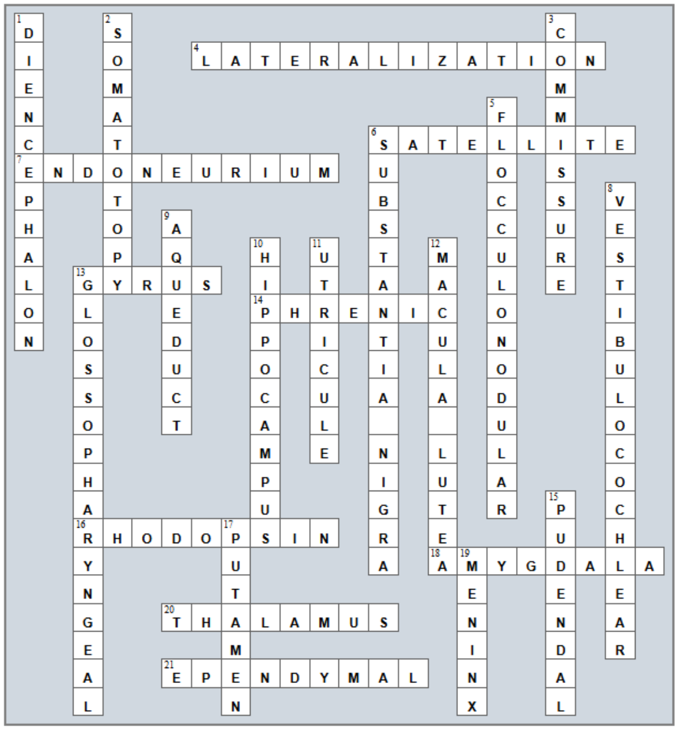
Answer key for: Crossword 6. Neuroanatomy (from previous page)



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